ANÆSTHETICS

ANÆSTHETICS

AND THEIR

ADMINISTRATION

A TEXT-BOOK FOR MEDICAL AND DENTAL PRACTITIONERS
AND STUDENTS

BY

FREDERIC W. HEWITT, M.V.O., M.A., M.D. CANTAB.

ANÆSTHETIST TO HIS MAJESTY THE KING; PHYSICIAN-ANÆSTHETIST TO ST. GEORGE'S HOSPITAL;
CONSULTING ANÆSTHETIST AND EMERITUS LECTURER ON ANÆSTHETICS AT THE LONDON
HOSPITAL; MEMBER OF STAFF OF KING EDWARD VII.'S HOSPITAL FOR OFFICERS;
LATE ANÆSTHETIST AT CHARING CROSS HOSPITAL, THE ROYAL DENTAL
HOSPITAL OF LONDON, THE ROYAL HOSPITAL FOR CHILDREN
AND WOMEN, AND THE NATIONAL ORTHOPÆDIC HOSPITAL

THIRD EDITION
WITH ILLUSTRATIONS

London
MACMILLAN AND CO., LIMITED
NEW YORK: THE MACMILLAN COMPANY
1907

First Edition published elsewhere.
Second Edition, Revised and Enlarged, 1901.
Third Edition, 1907.

PREFACE TO THE THIRD EDITION

In preparing this edition for the press I have endeavoured to incorporate within it all the new material which seemed to me worthy of incorporation without enlarging, to any great extent, the size of the volume. I have therefore been obliged to somewhat condense the pre-existing matter. The march of recent events has necessitated the interposition of a chapter on ethyl chloride; considerable amplification of the chapters dealing specially with chloroform; the addition of many fresh and important clinical facts concerning the incidence of surgical shock during anæsthesia; and a careful *résumé* of the increasing literature on the interesting and possibly important question of the relation between general anæsthesia and so-called "acid intoxication." Into the subject of surgical shock I have entered very fully, as the experience of the past few years has convinced me that this condition is a far more common complication of deep chloroform anæsthesia than is generally supposed.

It is a matter for congratulation that the examining bodies have at last made a course of instruction in anæsthetics a necessary part of the medical curriculum; and it is to be hoped that this reform may foreshadow others which are still urgently needed in this branch of practice. In the first place, legislation is required restricting the administration of anæsthetics, save in the most exceptional circumstances, to duly registered medical practitioners, and separating the responsibilities of the anæsthetist from those of the operator. As the

law now stands, anæsthetics may be administered by wholly unqualified persons, and in the event of any accident occurring from the anæsthetic, the legal responsibility would seem to be with the operator rather than with the anæsthetist. Surely the law should protect individuals who innocently submit themselves to the influence of the most powerful drugs in the British Pharmacopœia at the hands of those who are utterly ignorant of the risks involved; and surely the responsibility in administering an anæsthetic should rest with the administrator and not, as has been held, with the operator. Half a century ago, when operations were of short duration and anæsthetics were administered under the direction of the operator, there was perhaps some reason for the acceptance by the latter of the entire responsibility of the case. But matters have completely changed, and it not unfrequently happens in the surgery of to-day that the *rôle* played by the anæsthetist is of even greater importance than that played by the operator. The time has come, indeed, for a clear recognition of these two distinct responsibilities. Another reform needed is the appointment within our hospitals of an adequate number of officers for the special administration of anæsthetics, the senior of such officers being a member of the staff and possessing academic or professional qualifications similar in every respect to those required for other staff appointments at his particular hospital. This special department of practice should, in fact, be expanded in such a way that every anæsthetic within our hospitals is given by an officer appointed for such duties. This would, of course, increase the number of junior hospital appointments, but it would be of great advantage, not only to the public but to the profession, to have a constant stream of experienced anæsthetists issuing from our great centres of medical education. The present requirements of surgery, so far as the administration of anæsthetics is concerned, are of a totally different order from those which prevailed twenty or thirty years

ago when abdominal operations were in their infancy; and to meet such requirements the modern anæsthetist has come into existence. This product of recent times is not only able to obviate a considerable number of fatalities which would otherwise occur from the unskilled use of anæsthetics, but by adjusting his administrations so as to prevent surgical shock, by guarding against certain after-effects, and by other means, he is able to contribute in no small measure to the success of operations in general. Yet, curiously enough, there are still many thousands of educated men and women who look upon the process of anæsthetising, as practised by the now large body of special anæsthetists, as corresponding in its importance and responsibilities to poulticing, bandaging, or some other purely mechanical procedure, and who have little or no idea that the success of even the simplest surgical operation may be dependent to a large extent upon the anæsthetist. Is there not just as great a scope for professional skill and judgment when the respiratory, the circulatory, and the nervous functions of a patient are being profoundly modified by a general anæsthetic as there is during enteric fever or some other ailment for which the services of experienced physicians are generally regarded as essential? Yet it often happens, not only in hospital but in private practice, that the safety of a patient during perhaps the most critical hour of his life is entrusted to the mercies of one who has had little, if any, scientific training, and whose acquaintance with the powerful drugs he is handling bears an inverse ratio to the self-confidence displayed in their administration. This state of things is open to much criticism, and should certainly be remedied. Until some reforms of the kind here indicated have been introduced human life will continue to be sacrificed to an unnecessary extent, and the progress of surgery will be unnecessarily retarded.

To my colleague, Dr. J. Blumfeld, Anæsthetist to St. George's Hospital, I am greatly indebted for much valuable

assistance in bringing out this edition. To Dr. B. J. Collingwood, Demonstrator of Physiology at St. Mary's Hospital, my best thanks are due not only for his kindness in having looked through my two chapters dealing with the physiology of anæsthesia, but for having contributed a short article upon the absorption and elimination of anæsthetic gases and vapours—a subject at which he has specially worked. My indebtedness must also be expressed to Mr. Hugh Candy, Analyst to the London Hospital, for having been so good as to again read through my chapter on the pharmacology of anæsthesia. Finally, I wish to tender my thanks to Messrs. Barth and Company, of 54 Poland Street, Oxford Street, W., for the care with which they have manufactured for me many of the inhalers and appliances described.

I have done my best to make this book as it now stands as complete as possible, and I can only hope that the material within it may be found useful to those who, like myself, consider the subject of sufficient importance to justify the closest attention to detail.

FREDERIC W. HEWITT.

14 Queen Anne Street, Cavendish Square, W.
January 1, 1907.

PREFACE TO THE SECOND EDITION

In placing the second edition of this work before the profession, my first duty is to express my sincere thanks for the kindness and consideration with which the preceding edition was received. So greatly did this reception exceed my expectations, that it emboldened me to somewhat extend the original scope of the book, and to attempt a task which I had always felt myself incompetent to undertake—that of dealing with the history and experimental physiology of my subject. Hardly had I entered upon my new labours when the first edition became exhausted, and for upwards of two years, during which time the book has been out of print, I have been steadily devoting all my spare time to the production of the present volume, hoping to secure for it as favourable a reception as that accorded to its predecessor. But the work as it now stands is substantially a new one, and I therefore cannot help feeling some misgivings as to its future. Happily these are tempered by the reflection that in my endeavours to make the book as comprehensive and complete as possible I have been fortunate enough to obtain the assistance of numerous friends; and if I have any claim whatever to an indulgent hearing, this must be my chief plea. When I say that the MS. of the new chapters dealing with the experimental physiology of anæsthesia has passed through the hands of Dr. Leonard Hill, F.R.S., that Mr. Hugh Candy, B.Sc., F.C.S., has closely scrutinised all my chemical and chemico-physical statements, and that my colleague, Mr. H. Bellamy Gardner, in addition to kindly helping in many other

directions, has spent much time in collecting and comparing all the available facts bearing upon the history of anæsthesia, it will be seen that the assistance I have received has been of no mean order. I have striven, indeed, in this edition, to lay before the reader everything that is worthy of note in connection with the use and effects of general anæsthetics. It has been my aim to systematise the whole subject, so that information may be quickly obtained upon any chemical, physical, physiological, or clinical point. The interest which I personally take in the subject must be my excuse for having entered, in many places, into what may appear to be unnecessary detail. I have attempted to meet the requirements of the true student rather than those of men who are content to regard themselves, and to be regarded, as mere dispensers of drugs. It is an anomalous fact that the examining bodies have not as yet made instruction in anæsthetics a necessary part of the medical curriculum. When once this unsatisfactory state of things has been corrected, the importance of the subject will, I trust, be more generally recognised than it is at present.

FREDERIC W. HEWITT.

14 Queen Anne Street, Cavendish Square, W.
January 1901.

PREFACE TO THE FIRST EDITION

THE following pages have been written in the hope that they may prove of service to those practitioners and students who wish to obtain information concerning the administration and effects of general anæsthetics.

Until within the last few years, systematic instruction in this branch of practice was almost unknown; and even at the present time the opportunities which a student has of making himself proficient in the use of anæsthetics are, with rare exceptions, lamentably inadequate. It thus happens that numerous recently qualified practitioners leave their hospitals possessing but the scantiest knowledge of the subject; and owing to the bewildering mass of literature which exists, and to the difficulty of extracting any really practical information from it, they regard all further attempts at self-instruction as hopeless, and resort to the simplest rather than to the safest plans of anæsthetising their patients.

My principal object, therefore, has been to present to the practitioner a clear and yet detailed description of the best methods of inducing and maintaining surgical anæsthesia in ordinary cases; to indicate what modifications in procedure should be resorted to on exceptional occasions; and to systematically consider the chief difficulties and dangers connected with general anæsthetics, and the proper manner in which they should be met. I have endeavoured, in fact, to make the book one to which reference may be made when any doubt exists as to the anæsthetic which should be given in

any particular case. Supposing that a certain type of patient has to undergo a certain operation, and that the practitioner has not had much experience in the use of anæsthetics, it is believed that he will find, by referring to these pages, practical hints which may materially assist him in the conduct of the case.

Another object which I have had in view has been to assist the student in acquiring that knowledge which is essential before he actually administers an anæsthetic for a surgical operation. I have tried, as far as possible, to give him the information of which he seems most in need, if I may judge by the questions which are most frequently put to me whilst engaged in instructing students in the operating theatres of the hospitals with which I am connected.

I may add that I commenced collecting materials for this work just ten years ago. During this period I have taken as accurate notes as possible of every case which has presented points of interest, and have made comparative trials of all the best known methods of producing anæsthesia. In this manner I have attempted to give a solid clinical foundation to every conclusion which I have ventured to put forward.

About a year before going to press I received from Dr. W. J. Sheppard of Putney the collection of Note-books left by his brother, the late Dr. C. E. Sheppard, one of the anæsthetists at the Middlesex Hospital and at the Guy's Hospital Dental School. These Note-books contain most carefully recorded notes of 2350 administrations. I felt that I could pay no better tribute to the memory of one whose friendship it was my privilege to enjoy, and whose loss so many must regret, than by going most thoroughly through these notes, and extracting what I considered to be most important. By the kind assistance and guidance of Dr. W. J. Sheppard, I have been able to bring together all the valuable observations made by his brother upon the pupil under chloroform, and upon

many other points connected with the effects of anæsthetics; and I have incorporated these observations with my own.

In my endeavours to make this a clinical and practical treatise, I have thought it best to exclude much that might at first sight appear to be essential. Thus it will be found that only the more important general anæsthetics have been considered; that no detailed reference has been made to the discovery and history of the various means which have been employed for the prevention of pain; and that no attempt has been made, either to discuss the action of anæsthetics from a purely experimental point of view, or to harmonise clinical and physiological facts. All these aspects of the subject, although of great interest *per se,* are beyond the aim of the present volume, and have therefore been omitted.

In conclusion I am desirous of expressing my best thanks to Mr. Marmaduke Sheild and Mr. George Rowell for the very valuable assistance they have given me in passing the work through the press.

FREDERIC W. HEWITT.

10 George Street, Hanover Square, W.
July 1893.

KEY TO GENERAL ARRANGEMENT OF BOOK

Part I.—The History, Pharmacology, and Experimental Physiology of General Surgical Anæsthesia

Chap. I.	Chap. II.	Chap. III.	Chap. IV.
The evolution of general surgical anæsthesia.	The properties and impurities of the chief agents capable of producing general anæsthesia.	The theoretical and experimental physiology of general surgical anæsthesia. Part I. Introductory—General.	The theoretical and experimental physiology of general surgical anæsthesia (*continued*). Part II. Special Physiology.

Part II.—Preliminary Considerations before Anæsthetisation

Chap. V.	Chap. VI.	Chap. VII.	Chap. VIII.
The selection of anæsthetics, sequences, and methods in ordinary or routine cases.	The selection of anæsthetics, sequences, and methods in particular and exceptional cases. Part I. The state of the patient as a factor.	The selection of anæsthetics, sequences, and methods in particular and exceptional cases (*continued*). Part II. The surgical operation or procedure as a factor.	The extraneous circumstances of anæsthetisation.

Part III.—The Administration

Chap. IX.	Chap. X.	Chap. XI.	Chap. XII.	Chap. XIII.	Chap. XIV.	Chap. XV.	Chap. XVI.
The administration of nitrous oxide.	The administration of ether.	The administration of chloroform.	The administration of ethyl chloride.	The administration of ethyl bromide, ethidene dichloride, amylene (pental), and other anæsthetics.	Anæsthetic mixtures.	Anæsthetic sequences.	The use of morphine in conjunction with general anæsthetics.

Part IV.—The Management and Treatment of the Difficulties, Accidents, and Dangers of General Surgical Anæsthesia

Chap. XVII.	Chap. XVIII.	Chap. XIX.
Minor difficulties.	Respiratory arrest.	Circulatory failure.

Part V.—The Condition of the Patient after the Administration

Chap. XX.

The after-condition of the patient.

CONTENTS

PART I.—THE HISTORY, PHARMACOLOGY, AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

19.

CHAPTER I

THE EVOLUTION OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER II

THE PROPERTIES AND IMPURITIES OF THE CHIEF AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

b

CHAPTER III

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

PART I.—INTRODUCTORY—GENERAL

CHAPTER IV

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA *(continued)*

PART II.—SPECIAL PHYSIOLOGY

PART II.—PRELIMINARY CONSIDERATIONS BEFORE ANÆSTHETISATION

CHAPTER V

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN ORDINARY OR ROUTINE CASES

CHAPTER VI

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN PARTICULAR AND EXCEPTIONAL CASES

PART I.—THE STATE OF THE PATIENT AS A FACTOR

CHAPTER VII

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN PARTICULAR AND EXCEPTIONAL CASES (*continued*)

PART II.—THE SURGICAL OPERATION OR PROCEDURE AS A FACTOR

CHAPTER VIII

THE EXTRANEOUS CIRCUMSTANCES OF ANÆSTHETISATION

PART III.—THE ADMINISTRATION

CHAPTER IX

THE ADMINISTRATION OF NITROUS OXIDE

CHAPTER X

THE ADMINISTRATION OF ETHER

CHAPTER XI

THE ADMINISTRATION OF CHLOROFORM

A. Apparatus and Methods of Administration.

CHAPTER XII

THE ADMINISTRATION OF ETHYL CHLORIDE

CHAPTER XIII

ETHYL BROMIDE, ETHIDENE DICHLORIDE, AMYLENE (PENTAL), AND OTHER ANÆSTHETICS

CHAPTER XIV

ANÆSTHETIC MIXTURES

CHAPTER XV

ANÆSTHETIC SEQUENCES

(A) SIMPLE SEQUENCES

CHAPTER XVI

THE USE OF MORPHINE IN CONJUNCTION WITH GENERAL ANÆSTHETICS

PART IV.—THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER XVII

MINOR DIFFICULTIES

CHAPTER XVIII

RESPIRATORY ARREST

I. Treatment of Obstructive or Mechanical Respiratory Arrest

II. Treatment of Central or Paralytic Respiratory Arrest

CHAPTER XIX

CIRCULATORY FAILURE

PART V.—THE CONDITION OF THE PATIENT AFTER THE ADMINISTRATION

CHAPTER XX

THE AFTER-CONDITION OF THE PATIENT

ILLUSTRATIONS

PART I

THE HISTORY, PHARMACOLOGY, AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER I

THE EVOLUTION OF GENERAL SURGICAL ANÆSTHESIA

It is quite impossible to say at what period in the world's history attempts were first made to prevent or relieve physical pain, nor can we do more than speculate with the uncertainty of ignorance as to the precise means which were first adopted for the mitigation of human suffering. That the ancient Egyptians, Assyrians, and Chinese were familiar with many vegetable substances capable of producing pleasurable, sedative, and anodyne effects[1] all writers upon this subject are agreed, and there can be no reasonable doubt that they took advantage of these effects when practising the rudimentary surgery of the time. The earliest record of the use of a nepenthe or narcotic is to be found in the following passage from Homer's *Odyssey*:[2]—

> Presently she (Helen) cast a drug into the wine whereof they drank, a drug to lull all pain and anger and bring forgetfulness of every sorrow. Whoso should drink a draught thereof, when it is mingled in the bowl, on that day he would let no tear fall down his cheeks, not though his mother and his father died, not though men slew his brother or dear son with the sword before his face, and his own eyes beheld it.

The Bible and the Talmud also contain references to the ancient practice of inducing torpor or deep sleep by artificial means; whilst Herodotus specially makes mention of the

[1] For additional information respecting the early history of anæsthesia I would refer the reader to those writers from whose works I have myself collected much valuable information, viz. *Chloroform and other Anæsthetics*, by John Snow, M.D., 1858; *Leçons sur les Anesthésiques et sur l'Asphyxie*, by Claude Bernard, 1875; *Artificial Anæsthesia and Anæsthetics*, by Henry M. Lyman, 1883; and *Les Anesthésiques*, by Dastre, 1890.

[2] *Odyssey*, iv. 220. Butcher and Lacy's translation.

custom of the Scythians of inhaling the fumes of a certain kind of hemp, the effect of which was to produce an exalted mental state followed by sleep.

The earliest allusion to the employment of narcotics for the relief of pain during surgical operations appears in the writings of Dioscorides,[1] who lived at the beginning of the Christian era. He refers to the practice of boiling in wine the root of the *Atropa Mandragora* and of administering a certain quantity of the decoction

before operations with the knife or actual cautery, that they may not be felt.

Pliny,[2] too, who was contemporary with Dioscorides, makes similar statements as to the powers of the mandrake, and in addition informs us that the seeds of the Rocket plant (*Eruca*) were sometimes infused in wine and taken by criminals about to undergo the lash in order to

produce a certain callousness or hardihood of feeling.

In the second century Galen [3] makes mention of the

power of mandragora to paralyse sensation and motion ;

and about the same time Lucian,[4] a Grecian historian, wrote :—

He (Demosthenes) rouses his fellow-citizens, unwilling as if put to sleep by mandragora, employing his outspokenness as a sort of cutting and cauterisation of their apathy.

According to a French author,[5] there flourished in the third century a certain Chinese surgeon named Hoa-tho, who was in the habit of stupefying his patients, and possibly rendering them unconscious during surgical operations (incisions, acupuncture, amputations, etc.), by administering to them a preparation of hemp.

Coming to more recent times, we have evidence that in the thirteenth century of our era Hugo de Lucca, a Tuscan physician, prepared a certain oil with which he claimed

that by means of smelling alone he could put patients to sleep on occasions of painful operations ;

1 *De Med. Mat.* bk. iv. § 76.
2 Lib. xxxv. cap. 94.
3 Lib. vii. p. 207.
4 *Demosthenes' Encomium*, p. 36.
5 See *On Chloroform and other Anæsthetics*, by John Snow, M.D., p. 4.

but according to the testimony of Theodoric, his assistant, the vaunted preparation left much to be desired, for the patients had to be tied or held down by strong men. There can be no doubt, however, that it was the practice of many surgeons of the Middle Ages to produce some degree of stupefaction or insensibility during surgical operations, as is evident by the following extract from Du Bartas, a poet who lived in the middle of the sixteenth century:—

> Even as a surgeon minding off to cut
> Some cureless limb, before in use he put
> His violent engines on the vicious member,
> Bringeth his patient in a senseless slumber,
> And griefless then, guided by use and art
> To save the whole, cuts off the affected part.

In the year 1540, Valerius Cordus discovered sulphuric ether, but its narcotic properties were not recognised until three centuries later.

We are informed that in 1589 Giaubattista Porta, a surgeon who practised in Naples, used an essence made from hyoscyamus, solanum, poppy, and belladonna, enclosed in a leaden vessel, and

> the lid being opened, the patient would draw in by breathing the most subtle strength of the vapour, so that thereby he would be buried in a most profound sleep, nor be aware of what had been done to him.

Early in the seventeenth century, Shakespeare[1] makes Cornelius, a court physician, prescribe a drug which

> Will stupify and dull the sense awhile ;
> . . . but there is
> No danger in what show of death it makes,
> More than the locking-up the spirits a time,
> To be more fresh, reviving.

It was about this time that attempts were made in Italy, and particularly by Valverdi, to obtain unconsciousness by compression of the vessels of the neck—a procedure which is said to have been employed by the ancient Assyrians when circumcising children.[2]

In 1661 Greatrakes produced "magnetic sleep" by means

[1] *Cymbeline*, Act. i. sc. 5. [2] Claude Bernard, *op. cit.*

of stroking and making passes over the patient's body. A century later, in 1766, Anthony Mesmer evolved his theory of "animal magnetism" in a work on *The Influence of the Planets in the Cure of Disease.* After an almost equal lapse of time, James Braid of Manchester, in 1843, inaugurated modern hypnotism by the publication of his treatise on *Neurypnology, or the Rationale of Nervous Sleep.*[1] A few years later, while practising in India, Esdaile successfully induced hypnotic anæsthesia in a large number of native subjects, performing upon them a variety of surgical operations, many of which were, as the interesting records show,[2] of a severe character. From time to time, since the days of Esdaile, hypnotism has been similarly applied; but as success is only attainable with certain subjects, and as there are numerous moral objections to the system, hypnotic anæsthesia is now generally regarded as possessing scientific interest rather than any real practical value.

It was not until the very close of the eighteenth century that our modern system of anæsthesia began to be foreshadowed. Up to this time the various means which had been adopted for the prevention of pain during surgical operations had been utterly unreliable—in other words, true anæsthesia, in the modern sense of the term, had never been attained. But the discovery of hydrogen by Cavendish (1766), of nitrogen by Rutherford (1772), of oxygen by Priestley (1774), and of nitrous oxide by the last-named observer (about the same date), marked the commencement of a new era in chemical physics, and paved the way for the introduction into medical practice of a new, precise, and reliable system of inducing the most complete unconsciousness, and of maintaining this state for any reasonable time without injurious consequences. The medical world gladly welcomed the idea of the therapeutic employment of vapours and gases. Thus in 1795 we find Dr. Pearson of Birmingham employing ether as an inhalation for the relief of asthma. In 1798 a "Pneumatic Institute" was inaugurated at Clifton by Dr. Beddoes, and in this Institute

[1] See *Braid on Hypnotism.* New edition, 1899.

[2] *Natural and Mesmeric Clairvoyance, with the Practical Applications of Mesmerism in Surgery and Medicine*, by James Esdaile, M.D., 1852.

he proposed to treat phthisis and many other diseases by the inhalation of gaseous and vaporised substances. Mr. (afterwards Sir) Humphry Davy was then Dr. Beddoes's assistant, and carefully studied the action of nitrous oxide. On one occasion, when suffering from the pain of cutting a wisdom tooth, he inhaled this gas, and found the pain was thereby considerably mitigated. In the year 1800 he wrote :—

> As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in which no great effusion of blood takes place.

Curiously enough, as we shall presently see, this important suggestion was not turned to practical account in surgery till nearly half a century later.

As the effects produced by different gases and vapours became more generally known, distinct points of similarity began to appear between nitrous oxide and ether. The exhilaration and hilarity produced by the former led to the term "laughing gas." In 1818 an article, believed to have been written by Faraday, appeared in the *English Quarterly Journal of Science and Arts*,[1] containing the following interesting passage :—

> When the vapour of ether mixed with common air is inhaled, it produces effects very similar to those occasioned by nitrous oxide. . . . It is necessary to use caution in making experiments of this kind. By the imprudent inspiration of ether a gentleman was thrown into a very lethargic state, which continued with occasional periods of intermission for more than thirty hours. . . .

It was not an uncommon event, about this time, for lecturers upon scientific subjects to practically demonstrate the intoxicating properties of ether; and owing to the exhilarating and pleasurable sensations which the vapour produced, it became customary, particularly in certain country districts in the United States, for young people to engage in so-called "ether frolics." It is, indeed, to this latter circumstance that the discovery of surgical anæsthesia may be traced,[2] although it is

[1] I am indebted to Lyman for this and other references.

[2] See an interesting pamphlet by Dr. Marion Sims, *The Discovery of Anæsthesia*. Dr. Sims and Dr. Lyman, who have carefully sifted the conflicting evidence in the controversy as to the discovery of anæsthesia, agree in their views, and it is suprising that more attention has not been paid to the facts which they have collected.

difficult or impossible to decide to whom the chief credit of the discovery should be assigned.

There seems to be no reasonable doubt that in 1842 Dr. Crawford W. Long, a country practitioner, of Jefferson, Jackson County, Georgia, U.S.A., administered ether vapour with the distinct object and fortunate result of producing insensibility to pain during a surgical operation which he performed, and that he subsequently employed the same means with equal success. Long and his assistants had been in the habit of occasionally inhaling ether for amusement, and noticing that bruises had been unconsciously sustained not only by himself but by his assistants whilst in a state of ether intoxication, Long decided to test the anæsthetic effects of the vapour in surgical practice. He appears, however, to have taken no steps to make his important results known beyond the immediate circle in which he lived; indeed, it was not until some years later, when the rival claims of others were being hotly contested, that his own were brought forward and substantiated.

The next step in the evolution of anæsthesia took place in 1844, when Davy's predictions regarding the future of nitrous oxide in surgery became for the first time realised. In this year, Mr. Horace Wells, a dentist of Hartford, Conn., was present at a popular entertainment given by Mr. Colton, a lecturer on chemistry, and noticing, as Long had done in the case of ether, that one of the audience who had inhaled "laughing gas" had unconsciously sustained injuries whilst under its influence, he determined to test its merits as an anæsthetic in dentistry. He accordingly inhaled some of the gas, and a friend of his extracted a tooth for him without the slightest pain being experienced. The result was so marvellous that Wells immediately began to employ nitrous oxide in his own practice, and so convinced was he of the importance of his discovery that he soon gave a public demonstration in the surgical theatre of the Harvard Medical School. Owing, however, to the want of knowledge which necessarily prevailed as to the principles upon which the administration should be conducted, the demonstration proved a fiasco, and both Wells and his anæsthetic fell into undeserved discredit. For some

time, however, Wells continued to employ nitrous oxide in his practice, and with considerable success; but so keenly did he feel the contumely of his fellows and the failure of his hopes and schemes, that, on 14th January 1848, he destroyed his life. It is stated [1] that he opened a vein whilst in his bath, at the same time securing euthanasia by the inhalation of ether vapour.

The year 1846 is memorable as having witnessed the next advance, viz. the recognition and dissemination of the fact that by the inhalation of ether vapour complete surgical anæsthesia could be produced. In this year Mr. Wm. T. G. Morton, a former pupil and partner of Horace Wells, consulted the latter as to the manufacture of nitrous oxide. Wells referred Morton to a well-known chemist, Dr. Charles Jackson, who suggested that instead of employing nitrous oxide, Morton should try sulphuric ether, which was far easier to obtain. Acting upon Jackson's suggestion, and unaware of Long's results, Morton administered ether vapour in two or three dental cases, and with such success that he gave a public demonstration of his discovery in the General Hospital of Massachusetts on 17th October 1846, whilst Dr. Warren operated. This time the anæsthesia left little or nothing to be desired. It is regrettable that Morton tried to keep the nature of his anæsthetic a secret, securing a patent for it, and calling it by the name of "Letheon." Secrecy, however, was out of the question, owing to the characteristic odour of ether vapour; Dr. Bigelow soon detected the nature of Morton's anæsthetic, and at once sent the news to London, from which centre it is needless to say it rapidly spread throughout the civilised world.

From these facts it will be seen that the credit of the discovery of surgical anæsthesia, in the modern sense of the term, can hardly be ascribed to any one individual. Long, Wells, Morton, and Jackson, of whom America may justly be proud, were one and all instrumental in the great work. Although it is true that Long took no steps towards enlightening and benefiting the world at large by the remarkable discovery he had made, and that had it not been for the labours of his more enterprising countrymen, Wells and Morton,

[1] Dastre, *op. cit.*

the blessings of anæsthesia might for many years have remained unknown, his well-conceived and fearless line of action deserves no small degree of admiration and respect. To Horace Wells belongs the honour of first intentionally producing surgical anæsthesia by means of nitrous oxide, and of attempting to establish by a public demonstration that system of inducing insensibility to pain which has since spread into all countries. And to Morton our thanks are due as being the first to introduce ether into surgical practice, and to make known the possibility of maintaining continuous anæsthesia during surgical operations. It is a remarkable and deplorable fact that, with the exception of Long, all these pioneers in the hitherto untrodden field of practical anæsthesia ended their days with symptoms of mental aberration or actual insanity. The legacy, however, which they left behind them has proved to be, and will for ever remain, of incalculable value to humanity.

The first operation performed in England under a general anæsthetic took place at the house of Dr. Boott in Gower Street, London, on 19th December 1846. Dr. Boott had received from Dr. Bigelow the news of the discovery of ether anæsthesia, and he communicated this news to Mr. Robinson, a neighbouring dentist, who, having devised an inhaler for the administration, extracted a tooth from a patient without inflicting the slightest pain. Two days later Mr. Squire administered ether to two patients at University College Hospital; Mr. Liston amputating a thigh in the one case and removing an in-growing toe-nail in the other. On the 19th of January 1847, Dr. (subsequently Sir) J. Y. Simpson employed ether for the first time in midwifery practice, and found that the pains of labour might be wholly abolished without interfering with uterine contractions.

On 8th March 1847, Flourens announced to the Académie des Sciences [1] that chloroform exerted on the lower animals an anæsthetic action analogous to that of ether: but, curiously enough, little or no notice appears to have been taken of this observation. Later in the year, Simpson, who had for some time been endeavouring to find a less irritating and more convenient anæsthetic than ether, happened to consult Mr. Waldie,

[1] *Comptes Rendus*, t. xxiv. p. 342, 1847.

a scientific chemist of Liverpool, who suggested that chloroform, one of the constituents of "chloric ether," which was then therapeutically employed as a carminative, and contained chloroform mixed in varying proportions with rectified spirit, might be tried with advantage. Attempts had already been made to induce anæsthesia by means of the vapour of "chloric ether"; but such attempts had, for obvious reasons, failed. Simpson soon satisfied himself that the vapour of chloroform, the more active ingredient of "chloric ether," was capable of producing anæsthesia, and he lost no time in benefiting others by the discovery he had thus made. On 10th November 1847 he read a paper entitled "Notice of a New Anæsthetic Agent as a Substitute for Ether in Surgery and Midwifery"; and as a result of this paper, and of Simpson's subsequent writings, chloroform rapidly began to supplant ether in general surgery. This is not surprising, for its vapour was more agreeable, it less frequently induced struggling and intoxication, its action was more speedy, and it was altogether more convenient and manageable. It was for a while believed to be absolutely safe, but the death of a young woman named Hannah Greener, on 28th January 1848, soon dispelled this idea. From time to time similar casualties occurred, and it soon became apparent that whatever might be the advantages of the new agent, the administration of chloroform was by no means without its grave risks to life. As death after death was reported, all kinds of theories were advanced to explain them. The greatest ignorance, however, prevailed, and several years passed by without any definite light being thrown upon the causation of these melancholy accidents.

In 1847 Flourens also drew attention to the anæsthetic properties of ethyl chloride, and in the following year Heyfelder first administered the vapour of this substance for a surgical operation. Although Heyfelder's administrations were successful it was not until the year 1895 that ethyl chloride became a recognised general anæsthetic.

The first attempts to place the administration of chloroform and ether upon a sound and scientific basis were made by Dr. John Snow, whose classical work *On Chloroform and other Anæsthetics* was published in 1858. Snow investigated the

physical properties of the vapours of various anæsthetics; he performed a large number of experiments upon lower animals, with the object of determining the physiological effects which these agents produced; and he collected all the clinical and experimental evidence which was then available, in order to ascertain the precise way in which death occurred under chloroform, ether, and other gaseous or volatile substances. He was the first to describe the effects produced by the inhalation of definite percentages of chloroform vapour and air. He came to the conclusion that, in the case of chloroform, fatalities usually arose from primary cardiac paralysis, due to the inhalation of too concentrated a vapour; and working on this assumption, he devised and used the first chloroform inhaler by which the percentage of vapour could be regulated. Subsequent research has tended to show that some primary interference with respiration is generally present in chloroform casualties, although there can be no doubt that chloroform is, as Snow maintained, a direct cardiac depressant. Among the substances investigated by Snow, reference must be made to amylene—an anæsthetic which he was the first to administer, and one which he used in a considerable number of cases. The biography of Snow, written by his friend the late Sir B. W. Richardson, is full of interest, as showing the scientific enthusiasm with which Snow worked. To quote his biographer:

> His greatest deduction . . . and the proofs on which it is based, are to be found in his observations, where he explains that the action of the volatile narcotics is that of arresting or limiting those combinations between the oxygen of the arterial blood and the tissues of the body which are essential to sensation, volition, and all the animal functions. He demonstrated that these substances modify, and in large quantities arrest, the animal functions in the same way and by the same power as that by which they modify and arrest combustion, the slow oxidation of phosphorous and other kinds of oxidation unconnected with the living body when they (the narcotics) are mixed with atmospheric air.

By the death of Snow the advance of the subject suffered a distinct check. One of the results of his indefatigable labours was to direct attention to the hitherto unrecognised fact that by care and attention to detail deaths during anæsthesia could, to a very large extent, be avoided. Snow had not only shown himself to be an ardent seeker after truth, but a success-

ful and skilful anæsthetist: not only had he investigated the subject from its scientific side, but he had silently demonstrated the importance of what may be called the personal factor in anæsthetising. Of those who continued the work which he had begun there is no one to whom we are so much indebted as the late Mr. J. T. Clover, whose ingenuity and mechanical ability found such a happy sphere of activity in this department of practice. Snow's mantle, indeed, fell upon a successor who was conspicuously fitted to carry on the work which he had so ably begun. The first step taken by Clover was to perfect the principle of chloroform administration upon which Snow had laid such stress; and in 1862 he published an account of his chloroform inhaler, by which the administrator could adjust, more accurately than had hitherto been possible, the percentages of chloroform vapour and air. With this apparatus Clover anæsthetised a large number of patients, but not without becoming convinced that, so far as safety was concerned, chloroform was a less satisfactory anæsthetic than ether. He therefore set himself to the task of rendering ether anæsthesia as practicable as that of chloroform, and, as we shall subsequently see, this task he most successfully accomplished.

The physiology of anæsthesia next began to attract attention not only in this country, but throughout the world. In 1864 a committee of the Royal Medical and Chirurgical Society, which had been appointed "to inquire into the uses and the physiological, therapeutical, and toxical effects of chloroform," issued an important Report (see p. 401). They agreed, in the main, with Snow's conclusions as to the danger of concentrated chloroform vapour, and strongly recommended as a substitute for this anæsthetic a certain mixture of alcohol, chloroform, and ether, which had been originally proposed and used by Dr. George Harley, and which has since been extensively employed under the name of the A.C.E. mixture. Elaborate investigations into numerous physiological questions were also made at about this time by Claude Bernard, Benjamin Richardson, and others.

In 1867 Richardson introduced to the notice of the profession a new agent for producing general anæsthesia, to which

he gave the name "bichloride of methylene"; and for some time this substance, which was considered to possess many advantages over chloroform, was favourably received by surgeons. For reasons, however, which will appear in subsequent pages "bichloride of methylene" enjoyed but a brief reign.

In the same year, Dr. Junker described[1] his ingenious apparatus for administering chloroform—an apparatus which has proved to be of great value, more particularly in the surgery of the mouth, throat, and nose.

It was about this time that nitrous oxide began to regain the footing it had lost by Wells' untimely end and by the failures which had attended his earlier administrations. Its revival is attributable to the energetic advocacy of Colton, the lecturer at whose demonstration Horace Wells had, about twenty years before, conceived the idea of painless tooth extraction. In 1863 Colton formed an association in New York for the performance of dental operations under the influence of "laughing gas"; and the reports of his cases were so satisfactory that dentists began to give the matter their serious consideration. In 1864 Mr. Rymer, a London dentist, recorded several successful cases in which he had secured anæsthesia by means of nitrous oxide. It was not, however, till 1867, when Colton himself visited Paris and demonstrated before Dr. Evans, an English dentist practising in that capital, his methods of procedure, that the revived anæsthetic began to find widespread favour. On 31st March 1868 Evans came to England and gave a demonstration at the Dental Hospital of London (then in Soho Square); and on 7th December of the same year a joint committee of the Odontological Society and of the Dental Hospital issued a Report which was so favourable to nitrous oxide that from that time onwards this gas has occupied the foremost place amongst the anæsthetics of modern dentistry.

So many chloroform accidents had occurred during the twenty years that succeeded Simpson's discovery that many surgeons began to discard this anæsthetic and to return to ether. In the United States ether had held its own from the

[1] *Medical Times and Gazette*, 30th November 1867, vol. ii. p. 590, and 1868, vol. i. p. 171.

first; but in all other parts of the world, and more particularly in its native country, chloroform had to a very large extent supplanted its rival. The opportune discovery by Clover of the proper principles of ether administration greatly strengthened the position of the latter anæsthetic. Clover pointed out the advantages of air limitation during etherisation; he improved the methods for administering nitrous oxide; and he introduced the excellent system of using this gas as a preliminary to ether. In 1876 he published an account of his ingenious apparatus by which nitrous oxide and ether could be administered either separately or in succession; and in the following year he described his "portable regulating ether inhaler," which has since deservedly enjoyed a wider reputation than any other appliance of the kind. But the advances of ether were only partially successful in dethroning chloroform; for it soon became clear that, however safe ether might be, it was comparatively difficult to administer. A heated controversy as to the respective merits of the two anæsthetics began. The advocates of ether urged that accidents from its use were rarely met with, and that when they occurred there was nearly always some pathological condition present, constituting an important factor in the case. The supporters of chloroform, on the other hand, alleged that deaths during its employment were often deaths from surgical shock rather than from the toxic effects of the drug; that, provided the respiration were closely watched and the pulse disregarded, chloroform was perfectly safe; and that although ether did not, like chloroform, kill patients upon the table, it did so afterwards by causing lung complications. In subsequent years this Ether *v.* Chloroform question lost much of its supposed importance; for experience has shown that both anæsthetics have their respective spheres of utility. Chloroform has, however, retained its position in most parts of Scotland, in tropical countries, upon the battlefield, and, in those practices in which portability and convenience have to be studied; whilst ether has steadily continued to gain ground, and is at the present moment the chief or routine anæsthetic in most surgical centres of the United Kingdom and in many other parts of the world.

The next point which occupied the attention of those interested in the progress of anæsthesia was the precise action of chloroform, and, more particularly, of lethal quantities of chloroform upon the mammalian organism. The first purely physiological research upon this subject was conducted by the "Glasgow" Committee of the British Medical Association, whose report appeared in 1879. The Committee found that blood-pressure and cardiac action under chloroform were distinctly lowered, and whilst admitting that, in deaths from this anæsthetic, respiration generally ceased before cardiac action, they contended that the reverse might occur, that is to say, that the heart might be primarily paralysed. This view was in harmony with that advanced by Snow, but it was opposed to the principles laid down by Syme and the Edinburgh school. The famous Scotch surgeon had taught that chloroform never produced primary depression of the heart, and that, provided the respiration were carefully watched and the pulse disregarded, it was a perfectly safe anæsthetic. In order that this disputed point might be settled, the Nizam of Hyderabad, at the suggestion of Surgeon-Major Lawrie, who had for many years strenuously upheld the teaching of Syme, very generously granted a sum of money for still further prosecuting scientific research, and, as the result, the First Hyderabad Chloroform Commission was appointed. Numerous experiments upon lower animals were made, and the conclusions at which the Commission arrived were in complete harmony with the teaching of the Edinburgh school. The medical profession, however, hesitated in accepting these conclusions, and it was accordingly proposed to institute a Second Commission to carry out further physiological experiments upon a large scale. The Nizam again most liberally aided the project by supplying funds, and Dr. (now Sir) T. Lauder Brunton, who had been nominated by the *Lancet*, left England for Hyderabad in order to take part in the work. The voluminous Report of this Commission appeared in 1891, and in all essential details it corroborated the conclusions at which the First Commission had arrived. Finality, however, had not yet been attained; for not only was it soon shown by eminent physiologists that there were numerous fallacies in

the technical work of the Commission, but that many of the tracings upon which criticism had been invited were capable of interpretations differing from those assigned to them.

Amongst the numerous independent physiological researches which have been undertaken with the object of settling the chloroform question, mention must be made of the investigations of Bert, MacWilliam, Gaskell, Shore, Leonard Hill, Embley, Sherrington, Schafer, and Waller. Bert's researches, which will be found described in subsequent pages, were in reality little more than a repetition of those conducted by Snow many years previously, and the results at which the French observer arrived were in the main identical with those of Snow. MacWilliam, Gaskell, Shore, and Leonard Hill have successfully accomplished the difficult task of harmonising the more important of the conflicting facts with which the subject was surrounded when they entered the controversial field. It has been conclusively shown by them, and may be accepted as proved, that when chloroform is administered to the full surgical degree, it undoubtedly acts as a cardiac depressant. The subsequent researches of Sherrington and Sowton corroborate this view. In summing up the matter, therefore, it may be said that although there are some who still adhere to the Hyderabad doctrine, and regard chloroform as a drug which reduces arterial tension and depresses respiration, without interfering with cardiac action, the balance of present evidence is opposed to this view, and is in favour of the rival and more reasonable proposition, viz. that the fall of arterial tension which occurs is largely due to a direct effect of the anæsthetic upon the heart substance; and that whilst it is perfectly true that respiration usually ceases before the heart fails, it is the effect of the anæsthetic upon the circulation, and not its influence upon the respiration, which is the characteristic and principal element in chloroform syncope. For further details on this point the reader is referred to Chap. IV.

Although a considerable amount of literary, scientific, and inventive energy has been expended in developing the practical side of anæsthesia, singularly few noteworthy advances have been made in this direction since the days of Clover. The most important, perhaps, is the increasing recognition of

the fact that with all anæsthetics there is a tendency for obstructed breathing to take place and for anæsthesia thus to be complicated by varying degrees of asphyxia. Under the erroneous impression that chloroform deaths are invariably referable to undue vapour concentration, numerous ingenious appliances have been devised, particularly within the last few years, with the object of regulating more precisely than Snow and Clover had regulated, the proportions of chloroform vapour and air. The administration of oxygen with nitrous oxide has constituted another distinct advance, for it has placed within our hands a form of anæsthesia safer than any hitherto known. A proper appreciation of the influence of posture during anæsthetisation has also tended to improve our results with all anæsthetics. Although no new agent of any importance has been discovered, considerable use has recently been made of a substance which has for a long time been known to have anæsthetic properties—ethyl chloride. Finally we may say that, in addition to the usual anæsthetics, we have now so many mixtures and successions of these agents, and so many excellent methods of administration, that, provided the anæsthetist be thoroughly competent, anæsthesia may be induced and maintained with a minimum of discomfort to the patient, and with practically no risk to life.

CHAPTER II

THE PROPERTIES AND IMPURITIES OF THE CHIEF AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

A. NITROUS OXIDE

NITROGEN monoxide (otherwise known as protoxide of nitrogen, nitrous oxide, or "laughing gas") has the chemical formula N_2O. It was first prepared by Priestley towards the close of the eighteenth century.[1]

Properties.—Under ordinary conditions nitrous oxide is a colourless, transparent, feebly refractive gas, with a peculiar sweetish odour and taste. It may be respired without discomfort when the apparatus for its administration is properly constructed. When pure it is wholly devoid of irritant properties, so that it is particularly useful in cases in which other anæsthetics excite cough, swallowing, etc. The gas has a sp. gr. of 1·52 [2] (Colin). A litre of it weighs 1·97172 grm.; or 100 cubic inches, 47·29 grains. Water at 0° C. dissolves a little more than its own volume, but the solubility diminishes as the temperature of the water is raised. Nitrous oxide was first liquefied by Faraday in 1823. Liquefaction takes place under a pressure of 30 atmospheres at 0° C., or 50 atmospheres at 7° C. Liquefied nitrous oxide is a colourless, very mobile body, having a sp. gr. of ·9369 at 0° C. (Andreef). Its boiling point is stated by some observers to be −87·9° C., under a pressure of 767·3 mm. of mercury;

[1] Roscoe and Schorlemmer (*A Treatise on Chemistry*, 1884) give the date 1772; Watts (*A Dictionary of Chemistry*), 1776. The truth seems to be that the first preparation was in 1772, and the full recognition in 1776. See *Experiments and Observations on Different Kinds of Air*, by Joseph Priestley, vol. i. p. 118, and vol. ii. p. 175.

[2] 1·495 (Watts).

whilst others place it at $-92°$ C. The steel and iron cylinders in which nitrous oxide is supplied by the manufacturers contain the agent in this liquid form. Roughly speaking, 15 oz. by weight of liquefied nitrous oxide will furnish 50 gallons of the gas. Solid nitrous oxide, in the form of compact snow, has been prepared by Wills,[1] who obtained it by a modification of Thilorier's method for preparing solid carbonic anhydride. The temperature of its freezing- or melting-point is stated to be $-99°$ C., as observed with an alcohol thermometer. Sheppard pointed out[2] that the faulty working of nitrous oxide cylinders is often due to superficial solidification produced by the intense cold which results from the conversion of the liquid nitrous oxide into gas. Nitrous oxide is not easily decomposed, a considerable elevation of temperature being necessary to split it up into its constituent gases. When a burning body is placed in the gas, the latter is decomposed, and combustion is supported.

Impurities.—The nitrous oxide supplied for anæsthetic purposes is usually free from impurities.[3] It is stated, however, that the gas has sometimes been found to contain **other oxides of nitrogen,** and **chlorine.** These gases would give the nitrous oxide an irritating odour and would induce coughing. The former impurities would be best detected by passing a slow stream of the nitrous oxide through a cold solution of ferrous sulphate, acidulated with sulphuric acid; should the solution darken, the presence of other oxides of nitrogen would be indicated. Chlorine would be detected by its characteristic odour, and by its precipitating the chloride from a solution of argentic nitrate. Some writers state that "sulphates" may be present as impurities in nitrous oxide; but it is difficult to understand their existence in the gas.

Liquefied nitrous oxide may be preserved for an almost indefinite time in iron or steel cylinders. Some administrators[4] have drawn attention to differences between the gas obtained

[1] *Chemical Society's Journal*, II. xii. 21.

[2] See footnote, p. 268.

[3] Some years ago I had the nitrous oxide supplied to the Dental Hospital analysed by an eminent chemist. That obtained from one manufacturer was absolutely pure; that from another contained 1·2 per cent of oxygen.

[4] See *Brit. Journ. Dent. Science*, 15th Dec. 1884 ("Anæsthetics and their Administration," by J. W. Roberts, L.D.S.).

from liquid nitrous oxide and that which has never been subjected to liquefaction. Such differences probably depend upon the absence of all traces of atmospheric air in the nitrous oxide which issues from the cylinders. If nitrous oxide be kept in a gaseous form, even for a few days, admixture with air will be liable to occur.

B. ETHER

Ethyl oxide (otherwise known as ethylic ether, vinous ether, sulphuric ether, or simply ether) has the chemical formula $C_4H_{10}O$, or $(C_2H_5)_2O$. According to Watts[1] it was first prepared by Valerius Cordus in 1540, who gave it the name of "oleum vitrioli dulce."

Properties.—Ether is a transparent, colourless, very mobile, and highly volatile liquid, possessing a characteristic pungent odour and burning taste. It is perfectly neutral to test-paper. It refracts light strongly. The sp. gr. of pure ether is ·723 at 12·5° C. (Watts), or ·720 at 15·5° C. (Fownes). At 0° C. it is said to have a sp. gr. of ·7356 (Roscoe and Schorlemmer). According to Watts and Fownes it boils at 35·6° C. (96° F.) under the ordinary atmospheric pressure; but other observers (Kopp and Andrews) give the boiling-point as 34·9 C. Its vapour density, as compared to air, is 2·586 (Gay-Lussac), 2·565 (Snow); as compared to hydrogen, 37. Owing to its possessing such a high sp. gr., ether vapour may be poured from one vessel to another, and the process actually watched in bright sunlight. Olszewsky solidified ether, and found the melting-point to be −117° C. Ether is freely miscible with alcohol, chloroform, and almost all other hydrocarbon derivative compounds. It has been maintained[2] that when ether is mixed with chloroform in the definite proportions of their respective molecular weights a new chemical compound is formed, from which on distillation neither free chloroform nor free ether can be obtained. The fact that heat is generated when the mixture takes place is interesting in this connection. Ether is soluble to a certain extent in water, 1 part dissolving in 10 at 11° C. One part of water, moreover, dissolves in about 34

[1] Watt's *Dictionary of Chemistry* (new ed.), vol. ii. 464.
[2] *Journal American Med. Assoc.*, Feb. 1903.

parts of ether. Ether vapour is highly inflammable, and when mixed with air detonates violently on the approach of a burning body. It burns with a white luminous flame. These facts should be borne in mind, not only when administering in the neighbourhood of a naked flame, but when pouring the liquid from one bottle to another. The actual cautery should never be used about the mouth or nose when the patient is under the full influence of ether.[1]

Impurities.—Pure ethylic ether should be perfectly neutral to test-paper, and should evaporate without leaving any residue whatever. Many samples of the best methylated ether leave a distinct and pungent residue. It should, moreover, form a clear mixture in all proportions with oil of copaiba. Ether containing **water** or **alcohol** forms an emulsion with considerable quantities of the oil (Watts). The presence of water may also be detected by means of potassium phosphate, which is insoluble in anhydrous ether, but dissolves partially in ether containing water, a brown residue being left.[2] Tannic acid, which is insoluble in ether but soluble in water, is also used as a test for the latter. Wet ether gives turbidity with carbon bisulphide, and the Pharmacopœia (1898) includes among the tests of Æther Purificatus the following: "It should dissolve in an equal volume of carbon bisulphide (absence of excess of water)." Alcohol is best detected by shaking the ether with water, which removes the alcohol; the aqueous extract is then gently warmed, a few crystals of iodine added, and then so much caustic potash that the solution just becomes colourless; after standing for a few hours, or at most a night, a bright yellow precipitate of iodoform will be thrown down, and the characteristic six-sided tablets or six-sided stellar groups may be examined microscopically.[3]

[1] Kappeler (*Anæsthetica*, p. 173) refers to a case at Lyons, in which, during the use of the cautery in the mouth, the ether vapour ignited. The face of the patient and the bag of the ether inhaler caught fire, and deep burns upon the face resulted. The case is also referred to in the *Brit. Med. Journ.*, 1879, vol. ii. p. 2826. Mr. Marmaduke Shield records a similar case (*Proc. Med. Soc.*, 1887, vol. x. p. 144), and states that he has also known the expirations of a patient under ether to become ignited by an adjacent lamp. See also two cases reported in *Surgical Observations* by Dr. Warner.

[2] Romei, *Zeitschr. anal. Chem.*, 1869, p. 390.

[3] See Roscoe and Schorlemmer, vol. iii. part i. p. 318. See also Watts's *Dictionary of Chemistry*, 2nd Supplement, 1875, art. "Ethyl Oxide."

By this test 1 part of alcohol in 2000 parts of water may be detected. The presence of **methylated ether** in pure ether is best detected by careful fractional distillation.[1] When ether is kept in an imperfectly stoppered bottle it is said to absorb oxygen, and to become acid from the presence of **acetic acid.** It is difficult, however, to understand this, for, owing to its extreme volatility, the contents of the bottle would soon altogether disappear. Should acetic acid be present, the ether would, of course, redden blue litmus paper, and an aqueous extract of it would give the reactions for acetic acid. A dark red coloration with ferric chloride is not characteristic of the presence of acetic acid, as formates and other bodies give this reaction as well. Roscoe and Schorlemmer state that the most characteristic test is the conversion of acetic acid into cacodyl oxide: "For this purpose the acid is saturated with caustic potash, evaporated with a small quantity of powdered arsenic trioxide, and the mixture heated in a test-tube, when the characteristic smell is perceived." Should the aqueous extract contain **sulphuric acid,** it may be detected by the white precipitate (insoluble in hydrochloric acid), which it gives with baric chloride. The Pharmacopœia (1898) includes among the tests to which "purified ether" must conform the following: "On shaking with half its bulk of a dilute solution of potassium bichromate acidulated with sulphuric acid, and setting aside, the supernatant ether should have no blue colour (absence of hydrogen peroxide)." This apparently supersedes the starch test of the older editions, and

[1] Ether prepared from methylated spirit commences to boil at a lower temperature than ether prepared from rectified spirit. See an article by Mr. H. W. Jones, F.C.S., on "The Detection of Methylated Ether" (*Pharm. Journ. and Trans.* vol. xvi., 1885-86, p. 663). It is stated that as little as 10 per cent of methylated ether may thus be found. By removing the distillate immediately the thermometer indicated 90° F., the following results were obtained:—

100 c.c. of each taken.	C.c. obtained.	Remarks.
Rectified ether, sp. gr. ·720 . .	0	
Rectified ether, sp. gr. ·730 . .	0	
Methylated ether, sp. gr. ·717 .	60	Boiled freely at 74° F.
Methylated ether, sp. gr. ·720 .	54	
Methylated ether, sp. gr. ·730 .	23	
Rectified (·735) and methylated (·730) in equal parts	7	After cooling and again heating, a further 5 c.c. obtained.

indicates the official conclusion of the vexed questions to which that test gave rise.[1]

Sir William Ramsay, in an article which appeared in the *Nineteenth Century* for April 1898, is inclined to attribute the peroxide reactions sometimes given by ether to a peroxide of ethyl. It is perhaps a matter rather of theoretical interest than of practical importance, whether the effects should be attributed to hydrogen peroxide or to ethyl peroxide. In either case the effects due to the peroxide may be obviated by adopting the simple expedient of putting some clean mercury in the ether bottle as suggested by Sir William Ramsay in the same article. The mercury becomes oxidised at the expense of the peroxide which is thus decomposed, and, as no injurious volatile by-products are formed by the change, the suggestion seems as satisfactory as it is simple.

According to Martindale[2] the following kinds of ether are obtainable :—

(1) *From Pure Rectified Spirit*

(i.) *Æther* (Off.). Sp. gr. ·735. Ordinary medicinal ether. Contains a little spirit and water. Not so suitable for inhalation as—

(ii.) *Æther Purificatus* (Off.). Sp. gr. not exceeding ·722, and not below ·720.

(2) *From Methylated Spirit*

(i.) *Absolute Ether—Methylated.* Sp. gr. ·717-·719. Contains a little methylic ether, and is specially adapted for producing local anæsthesia, as it boils under 80°. Not adapted for producing general anæsthesia.

(ii.) *Rectified Ether.* From methylated spirit. Sp. gr. ·720. Well washed to free it from methylic ether, purified, and re-distilled. Well adapted for producing general anæsthesia.

(iii.) *Methylated Ether.* Sp. gr. ·730. For common purposes.

Putting on one side the first and third of the methylated ethers in the above list, which are used either for producing local anæsthesia or for common purposes, and which should never be employed for inhalation,[3] and putting on one side

[1] Prof. Dunstan and Mr. Dymond came to the conclusion that impure ether sometimes contains hydrogen peroxide, though they failed to produce it in pure ether by the prolonged action of oxygen.

[2] *Extra Pharmacopœia*, 1892.

[3] A fatal result has been known to follow the administration of "local anæsthetic ether" (see *Lancet*, 7th August 1875). These impure ethers, when inhaled, produce much irritation, respiratory difficulty, cough, salivation, etc.

also the ether standing first of all on the list, which is rarely used for inhalation, we are left with "Æther Purificatus" of the British Pharmacopœia, 1898, and "rectified ether from methylated spirit," or, as it is sometimes termed, "pure methylated ether." Opinions are still divided as to the relative merits of these two ethers. There are some who prefer the "pure methylated ether" to that obtained from rectified spirit; there are others who hold exactly opposite views; and there are others again who state that they can detect no differences in the effects of the two varieties. Mistakes are often committed in attributing certain clinical phenomena to this or that brand of ether. Whilst it may be regarded as highly probable that the purer ether possesses slight advantages over the methylated, the latter, if carefully prepared by a recognised manufacturer, is certainly quite suitable for hospital use.

C. CHLOROFORM

Trichlormethane, dichlorinated chloride of methyl, perchloride of formyl, commonly known as chloroform, has the chemical formula $CHCl_3$. Liebig, Soubeiran, and Guthrie appear to have independently discovered chloroform[1] in the year 1831; but its real chemical composition was not ascertained till 1834, when Dumas[2] determined its true formula.

Properties. — Chloroform is a colourless, transparent mobile, and volatile liquid, possessing a pleasant, penetrating odour, and sweet fiery taste. Its sp. gr. at 17° C. is 1·491 (Regnault); at 0° C. 1·52523 (Pierre). Chloroform obtained by crystallisation at an extremely low temperature (Pictet's

[1] According to Roscoe and Schorlemmer, chloroform was discovered in 1831 by Liebig (*Pogg. Ann.* xxiii. 444; *Ann. Pharm.* i. 31, 198), and about the same time, but independently, by Soubeiran (*Ann. Chim. Phys.* [2], xlviii. 131; *Ann. Pharm.* i. 272). The former considered it to be a chloride of carbon; the latter gave it the name "éther bichlorique." According to Watts (*Dictionary of Chemistry*), Liebig's discovery was in 1832; but as Liebig strongly put forward his claims to priority (*Ann. Chem. Pharm.* clxii. 161) it seems certain that, so far as he and Soubeiran were concerned, the discovery was almost simultaneous. Dr. Buxton (*Anæsthetics*, 2nd ed. p. 94) supports the claims of Samuel Guthrie, of Brimfield, Massachusetts.

[2] *Ann. Chim. Phys.* lvi. 115; *Ann. Pharm.* xvi. 164.

process) is stated to have a sp. gr. of 1·5002 at 15° C.[1] The boiling-point of pure chloroform, according to Regnault,[2] is 60·16° C. (140·2° F.); according to Liebig, 61° C. (141·8° F.). Wade and Finnemore,[3] who have carefully investigated the subject, state that pure chloroform boils at 61·15° with the barometer at 760 mm. Its vapour density as compared to air is, according to Dumas, 4·199; according to Regnault, 4·230. If the density of hydrogen be taken as 1, that of chloroform vapour is 59·75. Chloroform remains liquid and transparent at −16° C. (Pierre), but may be solidified by the cold produced by its own evaporation. Snow found that chloroform dissolves in about 288 times its volume of water. It is miscible in all proportions with alcohol, ether, and other organic liquids. It is not inflammable, but its vapour is decomposed when passed into a lighted spirit-lamp, and burns with a smoky flame, emitting fumes of hydrochloric acid.

According to Waller and Wells[4] a drop of chloroform from an average pipette weighs 20 mgm., and from a stoppered bottle 25 mgm., whilst the vapour of a drop when inhaled with an ordinary inspiration of from 400 to 500 c.c. of air, supplies a 1 per cent mixture of chloroform and air.

The following extracts from the writings of Snow may here be conveniently introduced:—

> There are three drops to a grain of the liquid, and as a minim of it weighs a grain and a half, there are nine drops in two minims. . . . One grain of chloroform produces 0·767 of a cubic inch of vapour at 60° F. when its sp. gr. is 4·2. . . . Serum of blood at 100°, and at the ordinary pressure of the atmosphere, will dissolve about its own volume of vapour of chloroform. . . . Under ordinary circumstances the vapour of chloroform has, of course, no separate existence, but is always mixed with air. It can exist in a pure state only when the temperature is raised to 140° or upwards, or when the pressure of the atmosphere is in a great measure removed by the air-pump. The quantity of vapour of chloroform that the air will hold in solution at different temperatures, under the ordinary pressure of the atmosphere, depends on the elastic force of the vapour of these atmospheres. It is governed by a law precisely analogous to that which determines the amount of watery vapour which air will hold in solution.
>
> The following table shows the result of experiments I made to

[1] Martindale's *Extra Pharmacopœia*.
[2] *Jahresb.*, 1863, p. 70.
[3] *Trans. Chem. Soc.*, 1904, vol. 85.
[4] *Lancet*, 9th July 1904, p. 76.

determine the quantity of vapour of chloroform that 100 cubic inches of air will take up, and retain in solution at various temperatures :—

Temperature Fahrenheit.	Cubic Inches.	Temperature Fahrenheit.	Cubic Inches.
Degrees.		Degrees.	
40	7	70	24
45	8	75	29
50	9	80	36
55	11	85	44
60	14	90	55
65	19		

In the above table, the air is a constant quantity of 100 cubic inches which becomes expanded to 107, and so on; but it may be convenient to be able to view at a glance the quantity of vapour in 100 cubic inches of the saturated mixture of vapour and air, at different temperatures, and in the table which follows the figures are so arranged as to show this :—

Temperature Fahrenheit.	Air.	Vapour.
Degrees.		
40	94	6
45	93	7
50	92	8
55	90	10
60	88	12
65	85	15
70	81	19
75	78	22
80	74	26
85	70	30
90	65	35

The **percentage composition** of mixtures of chloroform vapour and air containing between 3 and 12 per cent of the former may be rapidly estimated by the absorption of the chloroform vapour by olive oil.[1] For mixtures containing less than 3 per cent of vapour the simple and ingenious densimetric method introduced by Waller and Geets [2] should be employed.

This method consists in the direct weighing on a chemical balance of a flask of known capacity (circa 500 c.cm.), (*a*) filled with air, (*b*) filled with the mixture of chloroform and air. . . . 500 c.cm. of a 1 to 10 per 100 mixture of chloroform and air implies 5 to 50 c.cm. of $CHCl_3$

[1] See *Brit. Med. Journal*, 12th July 1902.
[2] *Op. cit.* 20th June 1903, p. 1421.

vapour weighing (on the assumption that 1 gram of liquid $CHCl_3$ = 200 c.cm. $CHCl_3$ vapour) 25 to 250 mg.—the weight of the volume of air displaced by the $CHCl_3$ vapour.

The weight of a litre of $CHCl_3$ vapour at 0° C =

$$\frac{12 + 1 + 106}{2} \times 0{\cdot}0895 = 5{\cdot}325 \text{ grams.}$$

The weight of a litre of air = 1·293 grams.

So that a litre of chloroform vapour is 4·032 grams. heavier than a litre of air. Or each c.cm. of chloroform vapour replacing 1 c.cm. of air gives an increased weight of 4·032 mg. Taking, then. 4 mg. as the additional weight due to the presence of each 1 c.cm. $CHCl_3$ in the mixture of air and chloroform (corrections for temperature and pressure not included) we have : In a 500 c.cm. flask each 1 per cent (= 5 c.cm.) giving an increment of 0·020 gm.; and in a 250 c.cm. flask each 1 per cent (= 2·5 c.cm) giving an increment of 0·010 gram. For practical purposes we can avoid calculation and estimate the percentage of chloroform vapour by a direct reading of the difference of weight of a 250 c.cm. flask, (*a*) filled with air, (*b*) filled with the mixture of chloroform and air to be titrated. The excess of the latter counted in centigrams, gives the percentage of the mixture : thus

an excess of 0·010 gram = 1·0 per 100
„ „ 0·050 „ = 5·0 „
„ „ 0·027 „ = 2·7 „

Collingwood[1] has also introduced an ingenious "tonometer" for estimating the percentage composition of atmospheres containing chloroform or other anæsthetics: his method being applicable for the estimation of chloroform percentages even when CO_2 is present.

The method is dependent on the following physical considerations :—

(1) At any given temperature a volatile substance will continue evaporating in a closed space until a certain definite percentage of vapour is present. If a manometer be attached, the percentage present can be calculated from the increase of pressure disclosed.

(2) If a certain percentage of the vapour of the substance be present in the vessel before the volatile liquid is introduced, then the amount vapourised will be lower ; and the diminution in the percentage vapourised will be equal to the percentage originally present. Thus by taking parallel readings of the manometer, the percentage originally present can be calculated.

In actual practice it is found to be more convenient to take differential than to take parallel readings, and, accordingly, this is the method adopted.

[1] *Proceedings of the Phys. Soc.*, 12th November 1904, and 25th February 1905.

For a description of the apparatus used and of the calculations which must be made, the reader may consult the papers referred to in the footnote.

Chloroform is found to be less liable to decomposition when a very small percentage of ethylic alcohol is added to it.[1] The chloroform of the British Pharmacopœia (1898) therefore contains sufficient absolute alcohol to produce a liquid having a specific gravity not less than 1·490, and not more than 1·495. Should alcohol be present to a greater extent than this the sp. gr. would, of course, be lower. It is stated that the chemically pure chloroform obtained by Pictet's freezing process does not require this addition of alcohol in order to preserve it;[2] but further research is necessary on this point.

It is doubtful whether there is any real advantage in practice in employing chloroform prepared from rectified spirit. The author has used methylated chloroform for many years and cannot satisfy himself that it is inferior to ethyl alcohol chloroform. He has also used acetone-made chloroform with equally good results. He is forced to believe, indeed, that there is little or no substantial foundation for much that has been written concerning the importance of employing this or that brand.

Impurities.—A great deal of discussion has from time to time taken place concerning the nature of the impurities of chloroform, and the possibility of such impurities having been responsible in some cases for the supervention of dangerous or fatal symptoms during chloroformisation. Whilst impurities and decomposition products have undoubtedly been found in chloroform which has produced dangerous symptoms, such symptoms have often appeared under the influence of chloroform which has stood with credit the recognised tests of purity. In the present unsettled state of the subject it will therefore be best that we should confine ourselves to facts, and avoid all inferences as far as possible.

The chloroform used for anæsthetic purposes should conform to the following tests:—

[1] Mr. David Brown Dott, writing on "The Purity of Chloroform for Anæsthetic Purposes" (*Pharm. Journ. and Trans.*, 1882, p. 769), states that one-tenth per cent of alcohol is sufficient.

[2] *Lancet*, 19th Dec. 1891: "On a New Method of Purifying Chloroform," by René de Bois-Reymond.

1. It should possess a sp. gr. and boiling-point[1] such as have been already mentioned.

2. It should be perfectly transparent and colourless.

3. It should be absolutely neutral to test-paper.

4. It should possess an agreeable, bland, and non-irritating odour.

5. When a portion is allowed to evaporate spontaneously from a watch-glass it should leave no residue, either of water or of any substance possessing a strong smell.[2]

6. When shaken with concentrated sulphuric acid no brownish coloration, or only the faintest, should result.

7. It should form no precipitate with a solution of argentic nitrate.

8. It should not acquire a brown colour when heated to the boiling-point with caustic potash.

Other tests of purity have been suggested. Several years ago M. Yvon drew attention[3] to the fact that an alkaline permanganate solution, when added to impure chloroform, is changed from violet to green, whereas the violet colour is retained when the chloroform is pure. Subsequent experience has shown[4] that the small quantity of alcohol which is usually added to chloroform is quite sufficient to change the colour of the permanganate, so that Yvon's test can hardly be depended upon.

Now that there are several reliable manufacturers of chloroform for anæsthetic purposes, the difficulty of obtaining a pure drug is far less than it was formerly. Chloroform may, how-

[1] Chloroform may be contaminated with substances possessing a higher or lower boiling-point than the chloroform itself. Thus Prof. Mentin of Warsaw (*Pharm. Journ. and Trans.*, 1888-89, p. 991) found, on taking 49 c.c. of a sample of chloroform which was obtained from a "respectable German house," that 6·5 c.c. came over at 59° – 60° C., 30 c.c. from 60° – 61°, and 12·5 c.c. above 61°. Other investigators have recorded similar results.

[2] Impure chloroform may leave a distinct residue when evaporated. For example, the residue of the sample referred to in the last footnote weighed ·002 grm., and consisted of well-defined acicular crystals surrounded by a yellowish liquid. It had a most disagreeable odour of nitro-benzol and tobacco, and when inhaled produced giddiness and headache. After forty-eight hours the smell was replaced by that of benzoic acid. When the residue was heated on a watch-glass and partly evaporated, the remainder turned brown and evolved a smell like that of burnt indiarubber. The chloroform from which this residue was obtained had caused alarming symptoms in one-half of the cases in which it had been employed.

[3] *Pharm. Journ. and Trans.*, 1882, p. 711.

[4] *Ibid.*, 1882, pp. 740-769.

ever, become decomposed, although, when protected by a small percentage of alcohol, as above mentioned, decomposition does not easily take place. It has been stated by Sir W. Ramsay[1] that exposure to sunlight and air will, in the course of a short time, lead to the formation of carbonyl chloride. This observer has found this body in many specimens of chloroform submitted to him for analysis, and states that it may be detected, on adding baryta solution to the chloroform, by a white film making its appearance at the junction of the two liquids. In the article to which reference has already been made (p. 24), he suggests keeping a little slaked lime in the chloroform bottle, so that should any carbonyl chloride form, it may be converted into harmless chalk and chloride of calcium.[2] Hydrochloric acid would, if present, be also removed by the lime. This acid and free chlorine have for several years been known to be present in chloroform which has undergone decomposition, and are to be detected by the chloroform reddening blue litmus paper, forming a precipitate with argentic nitrate, and liberating iodine from a solution of potassium iodide. **Acetic acid** (to be detected by the process described on p. 23), **formic acid**, and **aldehyde** are also stated by Kappeler to be produced by the decomposition of chloroform. The detection of **alcohol** is best effected by making a watery extract of the chloroform, and obtaining the iodoform reaction (p. 22). According to Kappeler, alcohol may also be conveniently recognised by the turbidity which results when equal parts of oil of almonds and chloroform are shaken together, or by the coagulation which takes place in white of egg when a few drops of the chloroform are added, or by the milky appearance which drops of chloroform assume when allowed to fall through distilled water.[3] When alcohol is present in excess of that quantity which is customarily added, the sp. gr. of the chloroform will, as already

[1] See *Lancet*, 23rd January 1897, p. 240. Dr. Newman and Sir W. Ramsay believed that they traced the supervention of dangerous symptoms and after-sickness to impure chloroform, but this is questionable.

[2] Messrs. Macfarlane & Co. maintain (*Brit. Med. Journ.* 16th March 1900) that carbonyl chloride cannot be readily removed in this way; and Mr. David Brown, F.C.S. (*Pharm. Journ.*, 24th December 1898, p. 669), urges that lime is much inferior to alcohol as a preservative of chloroform. The latter observer exposed chloroform to sunlight for 144 days, and found no trace of impurity at the end of this time.

[3] Kappeler, *op. cit.*

mentioned, be lower than 1·49. Alcohol, as well as other easily oxidisable substances, will, if present in chloroform, cause a cold solution of potassium bichromate acidulated with dilute sulphuric acid to turn green. Should **ether** be present it would, like alcohol, lower the sp. gr. of the chloroform. It may, moreover, be detected by dropping a watery solution of iodine into the chloroform. Should the drops remain of an amethyst colour and transparent, the chloroform is pure, but should the drops assume a dark red colour, ether is present. Crystals of nitrosodic sulphide of iron are insoluble in pure chloroform, but dissolve in the presence of ether or alcohol. Should **methyl compounds** be present they may be detected by the chloroform becoming dark-coloured or black when treated with concentrated sulphuric acid, or by a black oily layer forming when the chloroform is treated with chloride of zinc (Kappeler). According to Roussin,[1] pure chloroform shaken with di-nitro-sulphide of iron remains colourless; but if it contain alcohol, ether, or wood spirit, it will acquire a dark colour. Kappeler,[2] referring to this test, also states that the reaction is not only caused by the presence of ethylic alcohol and ether, but by aldehyde and amylic alcohol. According to Roscoe and Schorlemmer, pure chloroform does not attack bright metallic sodium, even at the boiling-point. Should the metal become coated with a white coating of chloride, the presence of chlorine compounds, such as **dichlorethane** or **ethylene dichloride,** may be assumed. As a corroborative test of the presence of these impurities, these authors state that the chloroform when heated with alcoholic potash evolves the combustible gas ethylene. In one of the 101 fatal chloroform administrations collected by Kappeler, **allyl chloride** was discovered in the chloroform, but the same chloroform had been used without bad effects in other cases. In another of these cases "higher combinations of chlorine" were found in the chloroform. But in nine of the fatal cases in which the chloroform used was examined no impurity was detected. The presence of **ethyl chloride** in a proportion so small as hardly to be detected by chemical means has lately been demonstrated in chloroform made from alcohol.[3]

[1] Watts's *Dictionary of Chemistry*, "Chloroform." [2] *Op. cit.*
[3] Wade and Finnemore, *Journ. Chem. Soc.* 1904.

This trace of ethyl chloride is absent in chloroform prepared from acetone. Chloroform made from alcohol is said to act more rapidly and efficiently than that made from acetone; and it is believed by some that these more satisfactory results depend upon the presence of this small proportion of ethyl chloride. The evidence, however, in favour of this theory is at present insufficient.

A few years ago Professor Pictet introduced a method of purifying chloroform by crystallisation. The chloroform is first subjected to a moderate degree of cold, in order to remove water and other easily crystallisable bodies. Intense cold is then applied and the chloroform crystallises, leaving a mother-liquor which is stated to retain any impurities that may have been present. The crystallised chloroform is then allowed to liquefy.[1]

Chloroform should always be kept in a cool, dark place, and in accurately stoppered bottles. As it is now an accepted fact that exposure to light and air is liable to set up decomposition, the drug should be obtained in small rather than large bottles.

This is perhaps the most appropriate place in which to draw attention to the interesting fact that chloroform vapour is **decomposed by contact with a naked flame**, phosgene and hydrochloric acid gases being formed, and the phosgene again splitting up, as indicated by the following equations: $2CHCl_3 + O_2 = 2COCl_2 + 2HCl$; and $COCl_2 + H_2O = 2HCl + CO_2$. When chloroform is administered in a small, badly-ventilated room, in which there is an oil or gas stove for heating purposes, or a gas burner or oil lamp for illuminating purposes, all occupants of the room, including the patient, will be liable to be affected by the irritant products of decomposition. Smarting of the eyes, burning sensations about the upper air-passages, dry spasmodic cough, and a feeling of oppression and tightness about the chest, may be experienced by those engaged in the operation. The smaller the room, the greater the number of naked flames, and the longer the

[1] See *Lancet*, 19th December 1891, p. 1415, and *Brit. Med. Journ.*, 23rd January 1892, p. 209. In the latter journal Dr. René du Bois-Reymond gives an account of "the toxic action of impure chloroform."

administration, the more marked will be the symptoms. The author has frequently experienced these sensations in a minor degree; and, curiously enough, has sometimes found the pungent odour more noticeable on leaving the room in which the operation has been performed than in the room itself. It is stated that occupants of operation rooms may suffer from persistent bronchial irritation, bronchitis, and even broncho-pneumonia after exposure to the fumes of the decomposed chloroform; and some observers have gone so far as to allege that patients undergoing operations may display such asphyxial symptoms from this cause as to render remedial measures necessary.[1]

D. ETHYL CHLORIDE

Ethyl chloride has the chemical formula C_2H_5Cl. Colin and Roubiquet[2] were the first to point out its true composition. It is a colourless, very volatile liquid with a sweetish taste and an aromatic, faintly pungent odour. Its specific gravity is 0·9214 at 0° C. (Pierre). The density of its vapour is 2·219 (Thènard), taking air as unity, and its boiling point is 12·5° C. (Regnault). It is very combustible, burning with a green flame with liberation of free hydrochloric acid. It is very soluble in alcohol. When thus dissolved the solution may be kept in well-stoppered bottles, and the ethyl chloride obtained by gently heating.

The **purity** of ethyl chloride may be roughly determined by its odour, by its leaving no residue when vaporised, and by its not reddening litmus paper. As there are now several reliable manufacturers of this anæsthetic, there is no difficulty

[1] It is difficult to say who first drew attention to the decomposition of chloroform by naked flame. The earliest reference I can find is in the *China Medical Missionary Journal* for December 1888, p. 160; but the anonymous writer of the short article therein refers to observations on the subject by "a contributor to a prominent medical journal." Iterson, Fischer, and Zweifel drew attention to the phenomenon in 1889; and in that year an article by Dr. Patterson, containing interesting personal experiences, appeared in the *Practitioner*, vol. xlii. p. 418. Zweifel reported a fatal case of bronchitis and pneumonia. See also *Lancet*, 12th March 1898, containing an interesting letter from Dr. J. J. Waddelow. See also *Birmingham Medical Review*, August 1892, containing an article by Dr. Charles Martin. The subject has attracted much attention on the Continent. According to Bréaudat (*Dict. de Physiologie*), the combustion of chloroform vapour gives rise to hydrochloric acid, and an acrid and acid oil containing several organic bodies; but he failed to find any $COCl_2$.

[2] Roscoe and Schorlemmer's *Organic Chemistry*.

in obtaining it in a state of perfect purity. The label upon the ethyl chloride tube should state that the contents are intended to produce *general* anæsthesia.

E. ETHYL BROMIDE

Ethyl bromide, bromide of ethyl, hydrobromic or bromhydric ether, C_2H_5Br, was first prepared by Serullas in 1827. It is a transparent, colourless, highly volatile liquid, of a strong sweetish ethereal odour and pungent taste. It has a sp. gr. of 1·4189 at 15° C. (Mendelejeff), and of 1·4733 at 0° C. (Pierre). Its vapour density, according to Marchland, is 3·754. It boils at 40·7° C., when the barometer stands at 757 mm. (Pierre). It is sparingly soluble in water, but mixes in all proportions with alcohol and ether. It burns, when ignited, with a green smokeless flame, bromine vapour being evolved. When exposed for some time to air, ethyl bromide decomposes and bromine is liberated.

The following are stated to be the common impurities of ethyl bromide, viz. free hydrobromic acid, free bromine, phosphoretted hydrogen, amyl and ethylene compounds, and sulphur compounds.[1]

According to Merck, ethyl bromide should stand the following tests: (1) when put on the hand it should evaporate quickly and absolutely, without residue, producing a marked feeling of cold; (2) the filtration with water should be neutral and should not change on the addition of nitrate of silver; (3) the addition of concentrated sulphuric acid should cause no discoloration.[2]

F. ETHIDENE DICHLORIDE

Ethylidene chloride, dichlorethane, or, as it is more commonly called, ethidene dichloride, was discovered by Regnault, who, from the mode of its preparation, gave it the name of monochlorinated chloride of ethyl. Snow was the

[1] *Brit. Med. Journ.*, 30th August 1902, p. 587.
[2] In the second test, *washing* with water is probably meant, *i.e.* the washings should be neutral, etc.

first to use ethidene dichloride as a general anæsthetic.[1] It has the chemical formula $CH_3 . CHCl_2$, and is a metamer of ethylene dichloride, or Dutch liquid. Ethidene dichloride is a transparent colourless liquid, resembling chloroform in taste and odour. According to Watts, its sp. gr. is 1·189 at 4·3° C. (Geuther); according to Roscoe and Schorlemmer, 1·2044 at 0° C. (Thorpe). The boiling-point of the purest samples has been found to be 60° C. (Beilstein and Krämer), four degrees lower than the boiling-point of the substance originally prepared and studied by Regnault. The vapour density of ethidene dichloride is 49·54.[2] It is distinguished from ethylene dichloride by its boiling-point (ethylene dichloride boiling between 83° C. and 84° C.) and by its behaviour with cold alcoholic potash, which decomposes Dutch liquid but has little or no effect upon ethidene dichloride. It is soluble in alcohol and ether, but is insoluble in water.

Clover found[3] that the ethidene dichloride supplied for anæsthetic purposes had not a uniform boiling-point, but could be divided, by fractional distillation, into two or more substances. That which he used had a sp. gr. of "1225," and a boiling-point of 46·1°, the temperature rising to 60°, at which point it boiled steadily till it was nearly all dissipated.

G. AMYLENE: PENTAL

Amylene, C_5H_{10}, was discovered by Balard in 1844, and first used as an anæsthetic by Snow. According to the latter authority, whose views have since been endorsed by all leading chemists, amylene is not a very definite compound, but a mixture of several isomeric bodies.[4]

Amylene is a colourless, thin, and very volatile liquid. Although not pungent when inhaled, its vapour has a disagreeable odour, somewhat resembling that of wood spirit. The liquid is almost without taste. The sp. gr. of amylene is

[1] The reader is referred to Snow's interesting article on "Monochlorurretted Chloride of Ethyle" (*sic*), *op. cit.* p. 420.

[2] For further information see Watts's *Dictionary of Chemistry*, vol. vii. 2nd Supp. 1875, p. 490.

[3] *Brit. Med. Journ.*, 29th May 1880, p. 797.

[4] See Roscoe and Schorlemmer, vol. iii. pp. 240 and 283. Also Watts's *Dictionary of Chemistry*, 3rd Supp. vol. viii. pt. i. 1879, p. 79.

stated to be ·66277 at 0° C., or ·6544 at 10° C. (Watts).[1] The sp. gr. of the amylene used by Snow was ·659 at 56° F. The boiling-point of amylene differs in different samples, and is not constant in the same sample. Balard placed it at 39° C., Frankland at 35° C., and Kékulé at 42° C. The vapour of amylene is inflammable.

At about the time of Snow's death, Duroy is said [2] to have carefully studied the boiling-point of amylene, and to have found that it varied widely—from 30° C. to 62° C. He found, moreover, that pure iso-amylene had a constant boiling-point of 38° C. (according to other observers, 35°). The name "pental" is applied to a pure form of amylene introduced into commerce by Mering.

[1] See *Ann. Ch. Pharm.* 4th Supp. 143.

[2] See *Brit. Journ. Dent. Science*, 1st June 1892, in which an abstract of a paper on "Pental" from the *Vierteljahrsschrift für Zahnheilkunde* appears. The paper is by Dr. Julius Kossa and Herm. Neumann of Budapest.

CHAPTER III

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA

PART I.—INTRODUCTORY—GENERAL

A. TERMINOLOGY: DEFINITIONS

THE agents whose chemical and physical properties have just been considered constitute the more important members of the therapeutic group known as **general anæsthetics.** The remaining members of this group are comparatively unimportant, for they are, so far as our present knowledge goes, incapable of producing such satisfactory effects as those obtainable by nitrous oxide, ether, chloroform, and the other substances to which reference has been made. Considerable differences of opinion exist as to the agents which should or should not be thus grouped together; and the question naturally presents itself: What is a general anæsthetic? To say that it is a substance which has the power of destroying conscious sensibility throughout the organism is hardly sufficient; for such a definition would include many therapeutic bodies which possess, so to speak, merely incidental anæsthetic properties, and which are more fitly included under other groups, such as narcotics, soporifics, anodynes, convulsants, etc. According to our present conceptions a general anæsthetic must possess the following properties:—

(*a*) It must be able to produce universal insensibility;

(*b*) It must be capable of being readily introduced into the circulation without discomfort to the patient;

(*c*) It must produce its effects gradually and progressively, so that its action may be under control;

(*d*) It must bring about not only general sensory paralysis, but such a loss of motor power as to render practicable the performance of the most delicate surgical operation;

(*e*) Its action upon the sensory and motor systems must not be associated with greater excitement, convulsive movement, or interference with respiration, circulation, or other important vital processes than can be controlled or corrected by the anæsthetist;

(*f*) And lastly, it is essential that the agent employed shall be of such a kind that when it has been withdrawn the whole organism shall resume its functions, and return to that condition in which it existed immediately before the anæsthetic was applied.

All agents fulfilling these requirements may be allowed a place in the group of general anæsthetics; and the more completely any agent fulfils such requirements the higher will be its place in the group. Anæsthetics such as nitrous oxide, ether, and chloroform thus occupy high positions; whilst others, such as amylene, nitrogen, etc., have but a questionable right to be included in the list.

There are very wide chemical and physical differences between the various substances whose physiological action we are about to discuss. They belong to no special chemical family; nor do they possess any distinctive element or group of elements in their composition. They are, moreover, equally dissimilar in their physical properties, for whilst most of them are liquid at ordinary temperatures, many are gaseous. Thus, the indifferent gases, hydrogen and nitrogen, by the simple exclusion of oxygen, will render patients completely unconscious—anoxæmic anæsthesia (see p. 456). Carbonic acid, too, when mixed with oxygen, has been shown to be possessed of anæsthetic properties (p. 138). Then, as we shall presently see, nitrous oxide (N_2O) has every claim to be regarded as a true anæsthetic. And other gaseous bodies, such as ethylene or olefiant gas (C_2H_4), methyl chloride (CH_3Cl), and methyl oxide ($(CH_3)_2O$), have been employed, with more or less success, for inducing general insensibility. As we pass from bodies which are gaseous at ordinary temperatures to those which are liquid, we find upon the borderland several highly

volatile agents, derivatives of hydrocarbons, such as ethyl chloride (C_2H_5Cl), which boils at the body temperature, methyl bromide (CH_3Br), and aldehyde ($CH_3 . CHO$). Then, as instances of anæsthetics with somewhat higher boiling-points, we have ethyl oxide, or "ether" ($(C_2H_5)_2O$), ethyl bromide (C_2H_5Br), and amylene (C_5H_{10}), all of which have been referred to in the preceding chapter. The next body generally placed upon the list is bichloride of methylene (CH_2Cl_2); but, as we shall see, this substance is, strictly speaking, improperly included. With a somewhat higher boiling-point than that of the preceding agent comes carbon bisulphide (CS_2), whilst acetate of methyl ($CH_3 . CO . OCH_3$) and acetone ($CH_3 . CO . CH_3$) are included amongst the general anæsthetics by some writers. Ethidene dichloride ($CH_3 . CHCl_2$), which has already been alluded to (p. 35), has a boiling-point (60° C.) almost identical with that of chloroform ($CHCl_3$). Amongst the less volatile bodies which possess general anæsthetic properties may be mentioned bichlorinated chloride of ethyl,[1] acetate of ethyl ($CH_3 . CO . OC_2H_5$), tetrachloride of carbon (CCl_4), ethylene chloride, or Dutch liquid ($CH_2Cl . CH_2Cl$), amyl hydride (C_5H_{12}), ethyl nitrate ($C_2H_5 . NO_3$), benzene (C_6H_6), and turpentine ($C_{10}H_{16}$). Alcohol ($C_2H_5 . OH$) can hardly be regarded as an anæsthetic, although, as is well known, it is capable of producing deep anæsthesia when administered in sufficiently large quantities. Finally, there are certain substances which are solid at normal temperatures, but which may, when administered in such a way as to enter the circulation, produce complete unconsciousness. Amongst these are: chloral ($CCl_3 . CHO$), acetal ($CH_3 . CH . (OC_2H_5)_2$), amyl chloride ($C_5H_{11}Cl$), and ethyl benzoate or benzoic ether ($C_6H_5 . CO . OC_2H_5$).

The term **general surgical anæsthesia** is commonly applied to that state of profound insensibility which is brought about by the action of a general anæsthetic, and which is of such a character as to allow of the performance of any surgical operation. In studying this state it is important to bear in mind that it may be either (*a*) simple or (*b*) complex.

[1] Mr. Hugh Candy informs me that there are two compounds which may be described as bichlorinated chloride of ethyl: (1) $CH_2Cl . CHCl_2$, boiling at 114° C.; and (2) $CH_3 . CCl_3$, boiling at 76° C.

(*a*) By **simple general surgical anæsthesia** is meant that state or condition which is distinctive of the simple action of a general anæsthetic, and which is unattended by any intercurrent complication materially affecting the respiratory, the circulatory, the nervous, or the muscular system.

This is the state or condition usually obtained by the experimental physiologist who, having anæsthetised his subject, introduces a tracheal cannula and administers through it a regulated anæsthetic vapour, thus providing, not only for the free ingress and egress of that vapour, but for the maintenance of unembarrassed breathing. It is rarely possible to parallel this state in the human subject. Occasionally, however, such a subject may be said to have passed into simple general anæsthesia. Thus, it may happen that a normal or healthy human being becomes anæsthetised with as little embarrassment to breathing as would have arisen had he been inhaling through a tracheotomy tube, and that when anæsthetised he is subjected to no surgical or other stimulus. Or the circumstances may be such as to make the parallelism closer, the patient, at the time of the administration, having a tracheotomy tube *in situ*, and no surgical operation to be performed. As a general rule, however, simple general surgical anæsthesia is not seen in practice.

(*b*) Under the term **complex general surgical anæsthesia** may be included all those states or conditions which are partly dependent upon the simple or normal action of a general anæsthetic, as just defined, and partly upon one or more intercurrent complications, due to other causes than the direct action of the anæsthetic and capable of materially affecting the respiratory, the circulatory, the nervous or the muscular system.

The various states or conditions thus included under one term are far more common in human beings than in lower animals—in the operating theatre than in the physiological laboratory. This is mainly owing to the fact that in the case of man it is customary to introduce anæsthetic gases and vapours through the complex and changeable upper air-passages above the trachea so that any altered position, spasm, or swelling of parts within or about those passages will be

liable to introduce an asphyxial element into the anæsthesia, and thus to convert simple anæsthesia into the complex variety. The various causes of intercurrent asphyxia will be subsequently discussed (pp. 529, 539, and 550). In the case of lower animals, anæsthetics are usually introduced through the trachea, so that no such intercurrent asphyxial states can arise. There is also another reason for the comparatively greater frequency of complex surgical anæsthesia in man, namely, that during general anæsthesia, and especially during deep chloroform anæsthesia, many of the surgical procedures of the operating theatre are attended by special and conspicuous vaso-motor effects which, although they may be paralleled in the lower mammal, as will be seen below (p. 77), are generally absent during the observations of the physiologist. The complex form of anæsthesia is the rule and not the exception when human beings are being anæsthetised—a few examples may be here cited.

In the so-called struggling stage of strong men the temporarily obstructed breathing from muscular spasm is the factor which makes the simple anæsthesia complex. During the operation of staphylorraphy there is often such a degree of intercurrent asphyxia that anæsthesia may be quite as much dependent upon this state as upon the chloroform which is being administered. When, during partially established anæsthesia, the sphincter ani of a muscular subject is dilated, and breathing suddenly ceases from reflex spasmodic tongue retraction or reflex laryngeal closure, a complex anæsthesia again results, the intercurrent asphyxial state possibly acquiring an importance out of all proportion to the simple anæsthetic state. Similarly, prolonged stertor of reflex origin may gradually but completely transform the one kind of anæsthesia into the other (p. 74). When, during the manipulation of the intestines of a patient deeply under chloroform, sudden vaso-motor paralysis occurs we are again brought face to face with complex chloroform anæsthesia differing widely from the simple state. Anæsthesia may at one moment be simple, at another complex. Or the complex state may resolve itself into the simple, as when tracheotomy is performed upon a patient whose breathing is embarrassed; the embarrassment, the cyanosis, and the feeble

pulse suddenly vanishing to be replaced by tranquil respiration, a natural colour, and a good peripheral circulation.

The above differentiation between simple and complex anæsthesia has been introduced, not with the object of considering the two states separately—for this would with our present limited knowledge be impossible—but with the hope of drawing the attention of all those who are interested in the physiology of anæsthesia to the important rôle played by the intercurrent complications to which reference has been made. It is, of course, necessary that we should know what effects general anæsthetics themselves produce, apart from all intercurrent complications during their administration; and a vast amount of important work in this direction has been done by our leading physiologists. We have also at our disposal valuable recent researches concerning one form of surgical shock. There yet remains for investigation the experimental physiology of intercurrent asphyxia, the presence of which, in one form or another, is the immediate cause of the vast majority of difficulties and accidents during anæsthesia.

The terms **open, valvular,** and **close anæsthetisation** will be defined and considered in the following section (B. The passage of the anæsthetic into and out of the organism).

The terms **dose, dosage, overdose,** and **overdosage** will also be defined and discussed in that section.

As the terms "syncope," "shock," and "collapse" will frequently be employed in this and other chapters, it may be well to say a few words by way of definition concerning them.

By **syncope** is meant a somewhat sudden, and as a rule, a temporary state of circulatory failure marked by pallor of the skin and mucous membranes, feeble, or imperceptible pulse, cold and clammy extremities, dilated pupils, separation of eyelids and irregularity, or in the worst cases arrest of breathing. Although syncope is generally regarded as essentially a cardiac condition, there can be no doubt that in many cases it is largely if not wholly due to an inadequate supply of blood to the cardiac chambers, and not to any intrinsic cause in the heart itself. Thus it is the prominent feature in those cases of surgical shock which arise from sudden dilatation of the

splanchnic area or from sudden and severe hæmorrhage. Similarly it may be the immediate result of an alteration in posture when the compensating mechanism for the effects of gravity is in abeyance (p. 129). Again the syncope which arises from stimulation of the cardio-inhibitory centre, whether by afferent impulses through the vagus or by (?) the anæsthetic directly affecting that centre, may be looked upon as of nervous rather than of cardiac origin. The syncope of asphyxia, the condition which obtains when cyanosis gives place to pallor, probably has many factors. The left heart receives less and less blood; the right heart is embarrassed by distention; and the heart muscle is poisoned with asphyxial blood. It is difficult to say whether, in the normal subject, syncope is ever purely and essentially cardiac in its nature. There is good evidence that when certain anæsthetics are administered in large doses the heart muscle may be suddenly paralysed; but it is highly probable that when anæsthetics are thus administered other important factors capable of bringing about circulatory failure come into play.

The term **shock** is most appropriately applied to serious respiratory[1] or circulatory states arising as the result of direct or indirect injury to some part or parts of the nervous system. From this definition, which the author ventures to put forward, shock may be—

(*a*) Primarily respiratory—called in this work for purposes of description **respiratory shock**;

(*b*) Primarily circulatory—**circulatory shock**; or

(*c*) **Composite shock**, *i.e.* respiratory shock rapidly followed by circulatory depression, or circulatory shock rapidly followed by respiratory depression.

These varieties of shock will be discussed when considering the reflex respiratory and circulatory phenomena of anæsthesia (pp. 74 and 76).

The use of the term **collapse** should be restricted to the more protracted and profound cases of circulatory depression.

[1] Although primary circulatory shock is far more common than primary respiratory I have thought it better, in dealing with this subject, to adopt this particular classification as it is more in harmony with the general plan throughout the book, of giving the first place to respiratory and the second to circulatory phenomena.

As a general rule there are several factors present in collapse. Profuse or protracted hæmorrhage, prolonged exposure or manipulation of parts rich in nerve-supply by which the vasomotor system and cardiac action become depressed, long-continued or unnecessarily profound anæsthesia by which the cardio-vascular system suffers dilatation, and respiratory embarrassment by which the respiratory nervous mechanism becomes exhausted, are instances of the more common causes which combine to produce this condition.

B. THE PASSAGE OF THE ANÆSTHETIC INTO AND OUT OF THE ORGANISM

Anæsthetics may act directly upon the organism by a simple process of imbibition and absorption. This is seen in the temporary arrest of development which takes place in germinating seeds when exposed to an atmosphere of ether or chloroform, and in the local loss of sensitiveness which occurs in the sensitive plant when similarly treated. Applied to the medusa, chloroform first arrests spontaneous movements and then brings about a state of diminished reflex activity.[1]

In organisms possessing a circulatory system, the absorption by the circulating fluid of the gaseous or vaporised anæsthetic will lead with greater or less rapidity to generalised effects; and this is true, no matter in what part of the organism the absorption takes place. Arloing has, for example, shown that general anæsthesia will become established in the sensitive plant when its roots are subjected to the action of an aqueous solution of chloroform.[2] In cold-blooded animals, such as frogs, Claude Bernard showed that so long as the circulation was intact the immersion of one half of the body in chloroformed water led to general anæsthesia; and he pointed out that, by reason of the comparatively slow elimination which takes place through the lungs, frogs are well fitted for this plan of inducing anæsthesia. General effects may also be produced in warm-blooded animals by the absorption of anæsthetics locally applied; but owing to the rapid elimination of volatile

[1] Brunton, *Pharmacology and Therapeutics*, 3rd edit. p. 111.
[2] Dastre, *op. cit.*

substances by the lungs, such effects are, as a rule, irregular and uncertain. Again, the gastro-intestinal tract may be made the site of absorption, as in the administration of chloral by the stomach, and of ether vapour by the rectum; but in this case also the results will be unreliable owing to the modifying influences exerted by digestion and other conditions. The most convenient channel for the introduction of gaseous and vaporised bodies into the general circulation is undoubtedly that presented by the respiratory passages, the large area furnished by the pulmonary alveoli and capillary network being particularly favourable to rapid absorption. Moreover, the blood circulating through the pulmonary arterioles and capillaries is specially suited for the reception and transmission of agents such as those we are considering; for immediately the blood has left the lungs it passes to the nervous centres in which take place, as we shall presently see, the essential changes necessary to the establishment of general surgical anæsthesia.

Putting out of the question, for the present, the administration of anæsthetic gases and vapours through a tracheal tube (*vide supra*), and assuming that we are dealing with a subject whose air-passages remain freely patent during both inspiration and expiration, it may be said that the effects produced by anæsthetics will depend in no small measure upon the precise system of anæsthetisation adopted. There are, in practice, three distinct systems of anæsthetisation, which may be termed (1) the **open**; (2) the **valvular**; and (3) the **close**. In the open system copious and undetermined quantities of atmospheric air gain access to the lungs with the gas or vapour, and all expirations freely escape into the surrounding atmosphere. This is the usual system by which chloroform is given from a handkerchief or Skinner's mask (p. 382). The term "semi-open" is sometimes applied to methods and inhalers by which a rather concentrated vapour is administered; but there is no essential difference between open and semi-open anæsthetisation. Mixtures consisting of chloroform and ether are usually given by so-called semi-open inhalers (p. 326). In the valvular system of administration both inspiratory and expiratory valves are present in the inhaling

apparatus, and, as a general rule, the constitution of the gas or vapour thus administered is known. In methods of this class each inspiration consists of a quantity (usually undetermined) of the particular gas or vapour; and each expiration escapes into the atmosphere. Nitrous oxide, nitrous oxide and oxygen, and percentage mixtures of chloroform are thus usually administered. Lastly, we have the close system of anæsthetisation. The apparatus used in close methods contains no valves, or if it contain valves these are prevented from acting; it possesses a face-piece capable of accurate coāptation to the face; and to this face-piece is attached a bag, usually of unknown capacity, into and out of which the patient breathes. When such an inhaler is accurately applied charged with a certain quantity of an anæsthetic, such as ether or ethyl chloride, the patient breathes backwards and forwards into the bag; the anæsthetic is vaporised and diffuses into the imprisoned air, and unless the inhaler be removed this imprisoned air gradually loses in oxygen and gains in carbonic acid. The effects produced by administering an anæsthetic by the close system will not only depend upon (1) the quantity of the anæsthetic gas or vapour available for respiration but upon other important factors, such as (2) the quantity of the air which becomes mixed with the gas or vapour; (3) the composition of this air; and (4) the duration of the rebreathing. With regard to the quantity of anæsthetic originally taken, this may be small or large. There is, for example, a great difference between the rebreathing of four litres and of twenty litres of pure nitrous oxide gas. The extent to which the gas or vapour becomes diluted with air will depend upon the quantity of that gas or vapour in relation to the combined quantities of air within the inhaler and air within the respiratory passages, the quantity of air within the inhaler being largely dependent upon the size and flexibility of the bag, and whether the inhaler has been applied during an expiration or during an inspiration. As to the composition of the air, this will depend upon the relative proportions of air from the respiratory passages and air from the bag. There will, of course, be a progressive change in the composition of the imprisoned air corresponding to the duration of the to-and-fro breathing. In close

anæsthetisation the oxygen of the air within the air-passages and bag will gradually diminish in amount, the carbonic acid excreted will increase, and the effects purely dependent upon the incarcerated anæsthetic gas or vapour will thus be intensified or modified according to the degree of oxygen deprivation and carbonic acid retention. As is pointed out elsewhere (p. 457) the inhalation, by the valvular system, of nitrogen with small proportions of oxygen, quickly leads to anæsthesia; and it is highly probable that in rebreathing methods, the oxygen limitation factor is of greater importance than the concomitant carbonic acid retention factor. At all events close anæsthetisation generally has the effect of markedly intensifying the action of an anæsthetic. The experiments of Haldane and Lorrain Smith[1] with regard to the effects of breathing different proportions of air and carbonic acid, of air with less than the normal percentage of oxygen, and of hydrogen, are interesting in this connection.

Having arrived within the pulmonary alveoli, anæsthetic gases and vapours are **absorbed** by the blood circulating through the pulmonary capillaries. Snow and Paul Bert believed that this absorption was a simple physical process, but recent researches tend to show, that there is, at all events with certain anæsthetics, something more than mere solution in blood. Speaking generally, however, it may be said that blood will continue to absorb anæsthetic gases and vapours till an equilibrium is established between alveolar and blood tensions. The rapidity of absorption will depend upon numerous circumstances, amongst which may be mentioned the degree of patency of the air passages, the rate of respiration, the depth of each respiratory act, the rate of the capillary flow through the alveolar walls, and the temperature of the blood. Should such a condition as laryngeal spasm exist, or should respiration be of such a character that the bases of the lungs expand but feebly, a considerable time may be occupied in obtaining anæsthesia. The influences of abnormal barometric pressures are discussed elsewhere (pp. 234, 303). As regards the influence of external temperature, Snow showed that the percentage of chloroform vapour inhaled from a handkerchief or inhaler when the

[1] *Journ. Path. and Bact.*, vol. i., 1892-93, p. 168.

external temperature was high was considerably greater than would be breathed from a similar surface when the external temperature was low.

The terms **dose**, **dosage**, **overdose**, and **overdosage**, which are often used in connection with the subject of general anæsthesia, are not always appropriately applied. Strictly speaking, a dose of a drug is a definite quantity introduced into the organism either by way of the alimentary tract, the lungs, or the subcutaneous tissues, with the object of producing some definite effect. In dealing with general anæsthesia, the term dose should be restricted to that quantity of the particular agent which has been taken up by the blood and tissues of the organism. It is important to remember that this has no necessary relation to the total quantity of anæsthetic administered. When an anæsthetic gas or vapour is progressively given by the valvular system until a point is reached at which the phenomena of full anæsthesia appear, it is, of course, possible to ascertain the quantity of the anæsthetic which has been used. But this quantity does not indicate the dose absorbed; for not only is the greater part of it dissipated in the patient's expirations, but at the termination of the administration there is still a portion of it within the respiratory passages. Although statements have been made by various observers as to the doses of anæsthetic which produce the different degrees of anæsthesia, our knowledge is not at present sufficient to warrant any very definite pronouncement upon this point (see pp. 107 and 370). More important, perhaps, than the question of dose is that of dosage, by which is meant the adjustment of the percentage of the gas or vapour in the atmosphere entering the respiratory passages. With dilute atmospheres the full narcotic effect of an anæsthetic may never be attained, the total quantity of the drug which the blood is able to absorb, *i.e.* the dose, being insufficient. With pure or nearly pure gases, *e.g.* with nitrous oxide free from or mixed with only a small percentage of air, or with concentrated atmospheres of volatile anæsthetics, *e.g.* with atmospheres containing chloroform vapour to the extent of 4 per cent and upwards, absorption quickly takes place till an equilibrium is established

between the blood and the gaseous contents of the lungs; the total quantity of the anæsthetic which the organism can absorb from such an atmosphere, *i.e.* the possible dose, is large; and unless the administration be suspended at the proper moment, an overdose may be given. When an anæsthetic is administered by the close system, the quantity used more nearly approximates to the dose or amount absorbed, but even with this system an unused portion of the anæsthetic vapour must remain. When, for example, a few c.c. of ethyl chloride are vaporised in a limited quantity of fresh or expired air, the amount of anæsthetic taken up by the blood and tissues may so nearly equal the quantity originally vaporised, that many writers speak of the latter as the dose.

We must not forget that, whilst the pulmonary blood-stream is the great medium for the reception and transmission of anæsthetics, it is also the medium for their **elimination**, and for the escape of carbonic acid. When, as the result of the withdrawal of an anæsthetic and the access of fresh air, alveolar tension falls below the blood tension, the gas or vapour which has been absorbed begins to be eliminated, and after a period varying widely according to circumstances, elimination becomes complete. There is no good evidence that any of the anæsthetics now in use are themselves decomposed during their period of association with the circulating blood. Waller, who has estimated the amount of chloroform recoverable from animals that have been anæsthetised, and Collingwood,[1] who has compared, in the same animal, the composition of the inspired and expired currents during chloroformisation, both agree as to the improbability, at all events in the case of chloroform, of any decomposition taking place. As regards carbonic acid, it would seem that, whilst its production is diminished during anæsthesia (see pp. 62 and 118), there is no obstacle to its elimination from the lungs, provided that the respiratory passages be free, and that expirations escape into the surrounding atmosphere. In the absence of all obstructive conditions and with open anæsthetisation the elimination of carbonic acid will largely depend upon the degree of lung ventilation present. Haldane and J. G. Priestley have shown that

[1] *Journ. Phys.* vol. xxxii.

the amount of lung ventilation at any time is regulated so as to maintain the same amount (or, more accurately, the same pressure) of CO_2 in the blood, the respiratory centre being at once stimulated by even the smallest increase above the normal amount. The fact that the CO_2 content of the blood rises largely during chloroform anæsthesia would seem to point to chloroform lowering the sensibility of the respiratory centre to the stimulus of CO_2 in the blood which reaches it. When breathing becomes, as it often becomes, more or less obstructed, it may be regarded as certain that this gas remains to some extent incarcerated below the obstruction, and that in consequence of this, its escape from the pulmonary blood will be retarded. Similarly, in close methods there is probably a progressive increase in the carbonic acid blood-tension, owing to the retention of the excreted gas within the air passages.

For the following valuable remarks on the absorption of anæsthetic gases and vapours the author is indebted to Dr. B. J. Collingwood, Demonstrator of Physiology at St. Mary's Hospital Medical School:[1]—

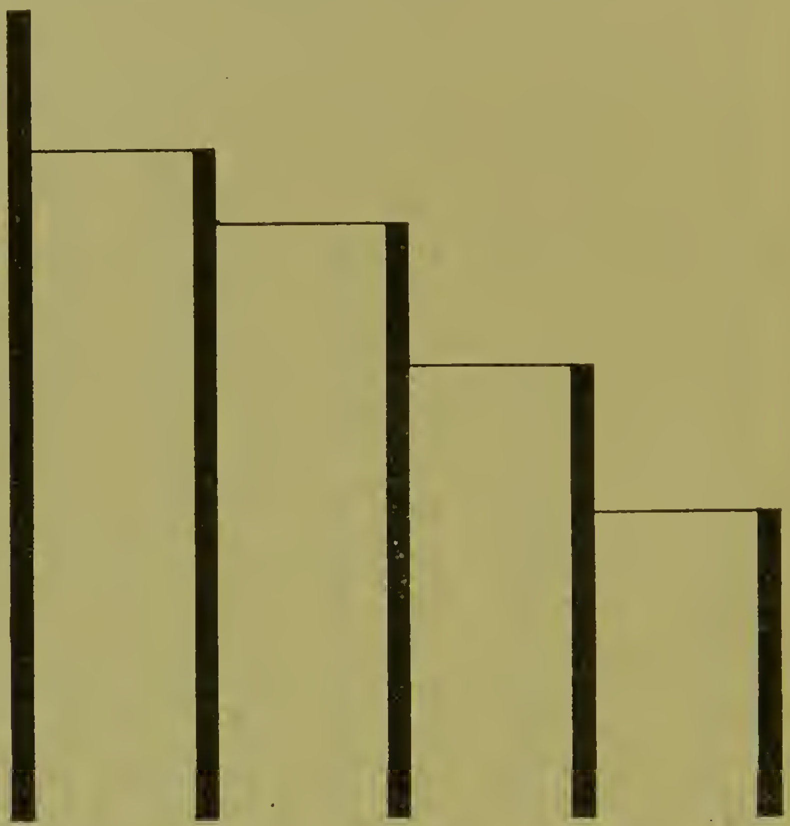
During the absorption of an anæsthetic by the organism the vapour or gas passes from the pulmonary alveoli to the blood, and from the blood to the lymph. For such to take place it is necessary that the pressure of the anæsthetic must be higher in the alveolar air than in the blood, and higher in the blood than in the lymph. In addition, if the percentage of anæsthetic in the inspired air be kept constant, the pressure corresponding to this percentage must be higher than that in the expired air, which again must be higher than that in the alveolar air. There is thus during the absorption of an anæsthetic a descending scale of pressures in the inspired air, the expired air, the alveolar air, the blood, and the lymph. The steepness of this scale will be greatest at the beginning of anæsthesia, and will diminish with the advance of narcosis. The scale can be rendered diagrammatically (see p. 52).

It is only the first step in this scale that can be directly estimated—that is the difference between the anæsthetic pressures in the inspired and in the expired air. We can, however, deduct that when this difference is great the whole scale will be steep; in other words, the pressure in the lymph will be considerably less than that in the inspired air. Early in anæsthesia, therefore, we should expect a marked difference between

[1] This short article by Dr. Collingwood is, to a large extent, a résumé of his Prize Essay on "Anæsthetics, their Physiological and Clinical Action" (University of London, 1905).

the concentration of anæsthetic in the inspired and the expired air. That this is the case experiments have shown.[1]

So far as the writer's knowledge extends no attempt has been made to estimate the vapour pressure in alveolar air during anæsthesia. One can, however, arrive at an approximate value by deductive methods. Oxygen affords a most instructive parallel, and the oxygen tension in



alveolar air has been estimated directly by Haldane and J. G. Priestley. The figures given by these observers show that the difference between alveolar and expired air oxygen tension is much less than that between inspired and expired air oxygen tension. Such a result is only to be expected when one considers that the "dead space" in breathing, as estimated by them, is considerably less than half (30 per cent) of the volume of tidal air. An approximate value of the alveolar tension of an anæsthetic can be reached indirectly as follows :—

Let the tidal air = 600 c.c.
Then the dead space will = 200 c.c.
Let per cent of anæsthetic in inspired air = 2 per cent.
Let per cent of anæsthetic in expired air = 1 per cent.

1 "Estimation of Inspired and Expired Chloroform," by A. D. Waller and B. J. Collingwood (*Proc. Phys. Soc.*, 25th Feb. 1905).

Then, as the dead space will contain 4 c.c. of anæsthetic (2 per cent in 200 c.c.), the alveolar air must contain 2 c.c. of anæsthetic (the total 6 c.c. of the expired air less the 4 c.c. in the dead space), and the percentage of anæsthetic in the alveolar must be 0·5 per cent. If we substitute $x+y$ for the percentage of anæsthetic in the inspired air, and x for the percentage in the expired air, and calculate on the "dead space" being one-third of the volume of the expired air, we find the following result:—

Inspired Air.	Expired Air.	Alveolar Air.
$x+y$ per cent Anæsthetic.	x per cent Anæsthetic.	$x-\frac{y}{2}$ per cent Anæsthetic.

Thus the difference in anæsthetic pressure between alveolar and expired air is only half the difference between that which exists between expired and inspired air. This ratio is represented in the diagram given on p. 52.

We must now consider what factors influence the first step in the scale, that is the difference in the percentage of anæsthetic in the inspired and the expired air. There are two main factors with which we must deal:

(1) The rate of absorption of anæsthetic by the blood.

(2) The frequency and depth of the respirations.

To discuss the first of these two factors, the rate of absorption of anæsthetic by the blood is affected by two factors: (*a*) the difference of pressure of the anæsthetic in the blood and in the alveolar air; and (*b*) the rate of the blood stream through the lungs.

In the early stages of anæsthesia when the vapour pressure in the blood is low, the rate of absorption will be most rapid, and, as a consequence, if the percentage in the inspired air be kept at a constant, the difference of anæsthetic concentration between the inspired and the expired air will be greater than in the later stages of anæsthesia. Therefore if the percentage of anæsthetic in the inspired air be kept at the same level, the concentration of the anæsthetic in the expired air will be constantly rising, and therefore also rising in the alveolar air, in the blood, and in the lymph. The conclusion is obvious, that *a safe percentage to administer early in anæsthesia is not necessarily safe in the later stages.*[1] In fact, a safe percentage early in anæsthesia may be a fatal percentage in the later stages. In the case of cats a 2 per cent vapour of chloroform is safe as a concentration for the *induction* of anæsthesia, but from the author's observations it is fatal if continued for about two hours. One cannot, therefore, answer the question, "What may be regarded as a safe percentage of chloroform to administer?" without first ascertaining to what period of anæsthesia this question refers.

We must now turn to the second factor which influences the rate of absorption of the anæsthetic, namely, *the rate of blood stream through the lungs.* It is clear that the slower the blood stream the less anæsthetic will be absorbed, for there will be a deficiency of supply of fresh blood

[1] *Science Progress*, p. 18, July 1906.

with a lower pressure of anæsthetic. But although less will be absorbed, yet the blood will contain a greater concentration of anæsthetic when it leaves the lungs, for it will have a longer exposure to the anæsthetic in the alveolar air. It thus follows that weakening of the heart's action is the first link in a vicious circle, for a feebler action of the heart will necessarily lead to a stronger concentration of anæsthetic reaching the left side of the heart, and thus tending to cause further weakening of beat.

We have lastly to consider the second factor which influences the difference between the percentage of anæsthetic in the inspired and in the expired air, namely, *the frequency and depth of respirations.* It is sufficiently obvious that increased frequency or depth of respirations will raise the percentage of anæsthetic in the expired and alveolar air more rapidly than would be the case with unaltered respirations. From such considerations it has been argued that it is actually an advantage to give a higher concentration of anæsthetic when the breathing becomes more shallow. But clearly one must proceed very cautiously along such a line of argument, for one must remember that feeble respiratory movements may be due to an overdosage of anæsthetic.[1]

An experiment conducted by the present writer may throw some light on the influence of the rate of respirations on the absorption of chloroform. A cat, two kittens, a guinea-pig, a rabbit, a rat, and a mouse were placed in a closed glass box, into which a 2 per cent vapour of chloroform was pumped. The animals were carefully watched, and the time of death in each case noted. The following table shows the results obtained :—

Animal.	Death after	Weight.
Mouse	30 minutes	17 grams
Rat	40 ,,	200 ,,
Kitten, No. 1 . .	120 ,,	200 ,,
Kitten, No. 2 . .	123 ,,	200 ,,
Rabbit	125 ,,	1500 ,,
Guinea-pig . . .	125 ,,	500 ,,
Cat	240 ,,	2330 ,,

Judging from this it would appear at first sight that a genuine idiosyncrasy exists to chloroform in some members of the animal kingdom. But a more careful scrutiny of the experiment did not support such a conclusion. It was evident that the animal which breathed the fastest died first, whilst the animal which breathed the slowest survived the longest. Hence the apparent idiosyncrasy resolved itself into a question of the different rates of respiration. The rate of respiration is dependent on the rate of heat loss, and the writer would suggest that this apparent idiosyncrasy amongst animals is largely dependent on the rate of heat loss. The very steps that a rapid heat

[1] *Science Progress*, pp. 20-21, July 1906.

loser must take to procure an extra amount of oxygen to maintain the temperature, will also procure an extra amount of anæsthetic in the blood.

In this connection some experiments performed by the writer in conjunction with Mr. H. L. F. Buswell are of interest. It was found that a percentage of chloroform which did not produce apnœa when inspired in natural respiration, did produce apnœa in about two minutes if rapid artificial respirations with the same percentage were established. Further, that these results were also obtained after section of the vagi, and also after addition of carbon dioxide to the mixture artificially respired. It appears, accordingly, that apnœa was produced not by vagal impulses following positive ventilation of the lungs, nor by the production of a low carbon dioxide content in the blood, but by the more rapid respirations causing a more rapid absorption and so a higher concentration of chloroform in the blood which paralysed the respiratory centre. If this conclusion be accepted, we must regard the rate of respirations as a most important factor in the absorption of an anæsthetic, for a safe concentration to administer during normal respirations may well become a dangerous one if the respirations increase in rapidity, unless they at the same time diminish equally in depth. Such considerations as these afford an additional reason for hesitating to pronounce an opinion as to what is or is not a safe concentration of anæsthetic to administer.

C. THE PHENOMENA OF GENERAL ANÆSTHESIA

I. The Phenomena of Anæsthesia in Lower Forms of Life

It has been long known that general anæsthetics are capable of arresting the germination of seeds, and of suspending or destroying the sensitiveness of the sensitive plant. When solutions containing ether or chloroform are applied to cilia which are in motion, the ciliary movement is interrupted, or ceases. Within the past few years the interesting discovery has been made that by exposing certain plants, such as the lilac and azalea, to the influence of ether or chloroform vapour, inflorescence may be considerably hastened.[1] Advantage is taken of this fact by those who grow flowers on a large scale for the market. In an interesting paper,[2] Professor F. J. Keeble has recently reviewed the effects of anæsthetics upon the lower forms of life. He finds that bacteria, except in spore condition, are killed by anæsthetic vapours. When cells

[1] *Lancet*, Jan. 9, 1904, p. 108. [2] *Ibid.*, Feb. 10, 1906, p. 377.

in process of division are exposed to anæsthetics, the process ceases so far as the cell itself is concerned. The nuclei, however, are unaffected. Ether and chloroform produce definite effects upon lower plant life, particularly upon the streaming movements, ciliary movements, and the throwing out of pseudopodia. Transient acceleration of movement and growth is observed with properly adjusted doses, but this is quickly followed by retardation and then by rest. Ether produces effects which are less powerful than those of chloroform and less likely to be permanent. Some interesting results were obtained with the tubers of gladioli. After exposure to the vapour of ether for twenty-four hours, the CO_2 produced by them rose from 12·2 milligrammes to 57 milligrammes for the first day, falling only to 40 for the third day. Professor Keeble states that ether is preferable to chloroform for hastening the inflorescence of plants. He also finds that when exposed to anæsthetics, plants lose their reflexes in an exactly similar manner to that observed in animals. By subjecting plants to suitable strengths of chloroform vapour, they are prevented from perceiving such a stimulus as the influence of gravity.

II. The Phenomena of Anæsthesia in Higher Forms of Life—General Surgical Anæsthesia

Having entered the pulmonary blood stream, general anæsthetics are enabled to exert their influence upon all parts of the organism, and to affect the various systems of that organism in a more or less definite and characteristic manner. As already indicated, there is a considerable difference between the effects produced by one anæsthetic and those produced by another, the organism and the means adopted for introducing the anæsthetic remaining the same. This is exemplified in the behaviour of the same patient under ether and chloroform, each administered in precisely the same way, and with the same percentage of air. Then, as everyday experience teaches us, the same anæsthetic may produce very different effects upon the same subject according to the system or method adopted for administering it. This is well seen in the case of nitrous

oxide, which is capable, according to the plan of administration adopted, of producing an asphyxial or a non-asphyxial form of anæsthesia. Again, the phenomena which arise during the administration of an anæsthetic will necessarily depend upon the rapidity with which the anæsthetic enters the circulation, and the quantity which is present within the circulation at the particular time. This was clearly demonstrated by Snow as regards chloroform, and it is true of other anæsthetics. In the next place, the effects produced by anæsthetics will depend, to some extent, upon the organism subjected to anæsthetic influence. There are, for example, certain differences between the effects produced by chloroform in man and the effects produced by this anæsthetic in lower animals. Finally, it is important to bear in mind that organisms, apparently similar to one another in all essential details, may display very different phenomena, even though precisely the same plan be adopted for inducing general anæsthesia. This is unquestionably the case with human beings, the type of subject, as we shall presently see (p. 152), being one of the most, perhaps the most important factor in determining the effects which this or that anæsthetic may bring about.

(*a*) The Respiratory Phenomena of General Surgical Anæsthesia

It will now be convenient to consider in an introductory and general manner the respiratory phenomena of surgical anæsthesia; and it will be better to study these as they present themselves in practice rather than to discuss them from the standpoint of the experimental physiologist. To the experimentalist, free and efficient breathing is dependent mainly, if not wholly, upon an intact and active nervous and muscular mechanism. Anæsthetics produce this or that change in the rhythm, rate, force, and amplitude of respiration by their action upon the nervous mechanism of breathing. They are regarded as substances which first stimulate, then depress, and finally paralyse this mechanism. But to the clinical observer respiration during anæsthesia has a wider and more important significance; for in actual practice as much attention has to be paid

to the degree of patency of the nasal, oral, pharyngeal, and laryngeal channels (through which anæsthetic gases and vapours, with their proper proportions of air or oxygen, have to pass, and through which such gases and vapours with carbonic acid have to be eliminated), as to the motive force of the respiratory pump, whose function it is to maintain the inspiratory and expiratory currents. In considering the effects produced by anæsthetics in the human subject, it is impossible to over-estimate the importance of the freedom, or the want of freedom, with which the respiratory current enters and leaves the lungs. Many phenomena customarily ascribed to the direct effects of an anæsthetic upon this or that part of the nervous or circulatory systems are often in reality referable to a greater or less degree of occlusion of the air tract, the presence and effects of which are not realised.

In practice the character of the breathing during the administration of an anæsthetic for a surgical operation will depend upon a large number of factors.

(i.) **The local action of the anæsthetic upon the respiratory passages** may induce cough, retching, swallowing, or "holding the breath."

(ii.) But provided no such disturbing influences arise, the normal breathing gradually tends to become somewhat deeper and quicker, chiefly from **stimulation of the respiratory centre by the circulating anæsthetic.** Some anæsthetics produce a more stimulating effect than others.

(iii.) In the case of pure nitrous oxide and of other gases and highly volatile vapours which admit of being administered with little or no atmospheric air, the concomitant **deprivation of oxygen** may lead to exaggerated breathing, stertor, and tonic or clonic spasm of the respiratory muscles (*vide infra*, (d) muscular phenomena).

(iv.) In certain methods of administering anæsthetics, inhaling-bags are used (p. 47), and some **re-breathing** therefore takes place: under such circumstances the incarcerated carbonic acid leads to a greater or less degree of hyperpnœa.

(v.) Again, **psychical impulses** may interfere with free respiration. This is sometimes seen early in an administration, when nervous, apprehensive subjects hold the breath till

cyanosis arises, or when hysterical subjects cry or laugh till a state of incipient asphyxia is brought about. It is quite possible that the association of extreme alarm and prolonged refusal to breathe may have been a factor in some of the fatalities which have occurred at the outset of chloroformisation (p. 406). When normal consciousness has just been lost, rapid or suspended breathing may result from a dream or hallucination.

(vi.) As the patient passes into the second stage of anæsthesia, respiration often tends to become modified as already indicated by **altered position, spasm, or swelling of parts within or about the upper air-passages** (see p. 529), or by **spasm of muscles directly concerned in the working of the respiratory pump** (see p. 550).

Various **respiratory sounds** may be emitted during the anæsthetised state. Whilst our knowledge as to their significance and immediate causation has certainly increased, there is need for further research concerning them. Provided the air-channels be thoroughly patent and the breathing be not laboured, the entry and exit of air to and from the lungs may be nearly or completely noiseless. But if the airway be at all restricted, respiration will increase in force and frequency and become audible. In addition to the sound usually made by the air current during deep breathing, there are numerous superadded or adventitious sounds which deserve attention. These may be divided into inspiratory and expiratory. The former are as a rule snoring, stertorous, or stridulous, the latter strained, phonated, or moist in character. Just as the sound ordinarily made during deep breathing may acquire a nasal or oral character according to the channels involved in breathing, so may certain of the adventitious sounds be similarly modified. Snoring is by far the commonest of adventitious sounds and is often, though by no means invariably proportional to the degree of anæsthesia. It always indicates a tendency towards occlusion of the air tract. It may be so soft as to be barely audible, or so harsh and rough as to be heard at a considerable distance. It is convenient to restrict the use of the word "stertor" to the latter variety of snoring. The commonest form of stertor during the anæsthetised state is that which is produced by the tongue

vibrating against the pharyngeal wall. This vibration is generally regarded as dependent upon a flaccid or paralytic state of the tongue; but the author is convinced that, in most cases, it is dependent rather upon spasm of muscles drawing the base of the tongue backwards during inspiration than upon a paralytic state of the organ. He has elsewhere[1] shown that with pure nitrous oxide the stertor is distinctly spasmodic, and that with mixtures of nitrous oxide and oxygen this stertor lessens as the oxygen percentage rises, till with certain mixtures the snoring is identical in all its characters with that of ether or chloroform anæsthesia. In certain subjects anæsthetics may cause so much muscular spasm about the fauces, palate, pharynx, floor of the mouth, and larynx, that an obstructive stertor is produced and life may thereby be threatened (see p. 535). In some cases, too, an engorged state of the tongue and adjacent parts obviously contributes to the production of stertor. Stertor may also be reflexly produced by surgical stimuli—"reflex stertor" (p. 74). Whilst stertor and snoring are the audible expressions of a greater or less degree of obstruction *above* the larynx, stridor always indicates a tendency towards occlusion of the larynx itself. Two varieties of laryngeal stridor present themselves in practice. The first of these is a short, deep, and coarse sound probably caused by collapse or falling together of the superior aperture of the larynx. The other variety is a prolonged and high-pitched sound, sometimes altering in pitch during inspiration, and dependent upon laryngeal spasm rather than upon collapse. In surgical practice laryngeal stridor may arise from the direct effect of the anæsthetic vapour, from the presence of mucus or other adventitious substances, or as the reflex result of some sensory stimulus, *e.g.* peritoneal traction (see p. 212). As regards expiratory adventitious sounds, these are, as a rule, phonated and dependent upon approximation of the true vocal cords. As a general rule any phonated sound indicates a moderate degree of anæsthesia. "Strained" expiratory sounds are generally if not always of pathological significance. Moist expiratory sounds indicate the presence of fluid immediately above, within, or below the larynx.

[1] *Trans. Roy. Med. Chir. Soc.* vol. lxxxii.

(vii.) When once the patient has been brought well under the influence of the anæsthetic, the respiration may usually be made to vary with the **quantity of the anæsthetic given**, becoming deeper, quicker, and (often) more stertorous with more, and shallower, slower, and (often) less stertorous with less. Respiration is chiefly performed by the diaphragm during anæsthesia, the sternum and intercostal spaces receding somewhat during each inspiratory act. In young athletic subjects, however, inspiration may be chiefly thoracic, being effected principally by the intercostal muscles. Whenever any slight impediment to the free entry of air takes place, whether in athletic or other subjects, breathing tends to become diaphragmatic, the chest walls, particularly when the obstruction is considerable, receding with each jerk of the diaphragm. Expiration is a less passive process than in the conscious subject, the recti and other abdominal muscles often taking part in its performance. The respiratory phenomena of overdosage are considered under the respective anæsthetics.

(viii.) In addition to the respiratory changes which are strictly dependent upon the action of the anæsthetic itself upon the respiratory centre, there are other changes which are dependent upon the **blood supply to that centre**. Other factors remaining the same, the better the arterial supply the better the breathing, and *vice versa* (see pp. 117 and 561).

(ix.) Any hindrances to free thoracic and abdominal movement, such as **tight-lacing**, the adoption of **certain postures**, etc., may readily introduce an asphyxial element into the administration (p. 550).

(x.) In certain cases "**physiological apnœa**"[1] may be met with. It is most common under nitrous oxide and oxygen, but it may appear under other anæsthetics, and is nearly always preceded by a phase of rapid and deep breathing. According to a recent research by Haldane and J. G. Priestley,[2] apnœa is dependent upon a fall of CO_2 pressure in the respiratory centre to below the "threshold exciting value," the oxygen pressure

[1] In this work the term "apnœa" is restricted to that form of suspended breathing which is associated with a good pulse and colour. It seems to the author that apnœa is an inappropriate term for any of the varieties of respiratory arrest discussed in Chapter XVIII.

[2] *Journ. Phys.* vol. xxxii. p. 225.

being at the same time sufficiently high not to excite the centre.

(xi.) **Cheyne-Stokes breathing** is sometimes seen, particularly in elderly and feeble subjects, under chloroform. In practice it is certainly rarely if ever observed during an administration attended by re-breathing.

(xii.) In practice it will be found that the rate, rhythm, and amplitude of respiration undergo important modifications dependent upon the **operation** itself. Traumatic, thermal, and electrical stimuli are all capable of modifying breathing, either in the direction of augmentation or in that of arrest. The modifications, which are as interesting as they are important, will be specially discussed when dealing with the reflex phenomena of anæsthesia (p. 70) and respiratory shock (p. 74).

It is generally admitted that **respiratory exchanges** are greatly modified during anæsthesia. Thus, Rumpf found with ether, chloroform, alcohol, and chloral a decrease of 40 per cent, and a corresponding diminution of temperature. Richet[1] found that chloralised dogs only produced on the average ·600 gm. of CO_2 per kilo. per hour, whilst normal dogs produced 1·200—in other words, the chemical activity of the organism was reduced 50 per cent.

The rapidity with which a given anæsthetic produces its **effects** will greatly depend upon the rate and depth of the respiratory movements, and the activity of the pulmonary circulation, a quick and deep respiration and a forcible and full pulmonary blood-stream being favourable to absorption and rapid transmission of the anæsthetic.

It is clear from the foregoing facts that the respiratory phenomena of general surgical anæsthesia are dependent upon three main factors: (1) The **activity of the respiratory centres**, *i.e.* the amount of nervous energy available for the working of the respiratory pump: (2) The **degree of patency of the upper air-passages** through which the respiratory current passes: and (3) the **state of the respiratory pump itself**, particularly as regards the presence or absence of any external impediment to lung expansion. Given the absence of all conditions capable of depressing the activity of the nervous mechanism

[1] *Dict. de Physiologie.*

of breathing, a free air-way, and the absence of any hindrance to lung expansion, respiration will be satisfactorily performed. On the other hand, no amount of energy in the nervous mechanism of breathing will be of any avail when an occluded air-way is present, or when there is some external condition at work preventing lung expansion. Both minor and major degrees of occlusion of the air-way may exist with but little audible evidence, and the intercurrent asphyxial state thus induced may escape attention. So closely may minor anoxæmic or asphyxial symptoms resemble those of anæsthesia, so nearly may the phenomena of the latter simulate those of the former condition, and so easily may the one state be made to intensify the other, that we cannot help being struck by the analogy existing between them.

(*b*) The Circulatory Phenomena of General Surgical Anæsthesia

The circulatory phenomena of general surgical anæsthesia have for many years been the subject of much controversy, and a large number of important researches have been conducted concerning them. Although each anæsthetic brings about circulatory states more or less special to, and characteristic of that anæsthetic, so that generalisations must be made and received with caution, it is important that certain cardinal points concerning the circulation during anæsthesia should be understood before considering these special or characteristic states in the following chapter.

The state of the circulation of a normal subject at any given moment during anæsthetisation for a surgical operation will depend upon a variety of factors. Unfortunately our knowledge is insufficient to enable us to enumerate all of these, or to place those with which we are acquainted in their true order of importance.

Before consciousness has been completely destroyed by an anæsthetic, the circulation is liable to disturbances of **psychical** origin. Of these, cardiac acceleration is usually the only noticeable phenomenon. Highly nervous and apprehensive human beings may, however, display pallor or even slight

lividity during the initial stages of anæsthetisation, and these phenomena may persist till full anæsthesia has been secured. Cases have been recorded in which patients have suddenly died from fright immediately before the inhalation of an anæsthetic, the probable explanation of such accidents being that psychical disturbance has so profoundly affected the cardiac and vaso-motor centres that syncope has resulted. It is, of course, conceivable that such an event might occur in a highly nervous and excitable subject during the first few inhalations of an anæsthetic, the latter being in no sense responsible. The influence of the psychical state as a factor in chloroform accidents will be specially considered in later pages (p. 406).

When consciousness has been destroyed the state of the **respiration** already discussed (p. 57) is undoubtedly the most important factor in determining the state of the circulation; the rate, force, and amplitude with which the respiratory pump works, the freedom with which lung expansion, contraction, and ventilation take place, and the state of the blood so far as its respiratory gases are concerned, having very material influences upon both the greater and the lesser circulation. Efficient respiration is necessary for efficient circulation. A *barely noticeable* degree of obstruction to air-entry leads to a good type of breathing and hence to good circulation. When the degree of obstruction increases, the venous system will begin to show signs of over-fulness, the veins at the site of operation bleeding more freely than usual, and the tongue increasing in size so that it projects between the teeth. This altered distribution of blood, however, may be quite compatible with a good pulse, so long as the obstruction remains slight. It is very common in practice to find *nasal* respiration associated with these circulatory changes, simply because such respiration is usually inadequate; directly free oral breathing is secured, the veins cease to bleed and the tongue lessens in size. The degree of venous fulness and the rapidity with which it is brought about will depend upon the total quantity of blood and the state of the tissues. In some subjects a rapidly advancing and dangerous venous swelling of the tongue and adjacent parts may

quickly follow arrested breathing. (See Illustrative Case No. 42, p. 536.) It is not uncommon, in the case of rather feeble and anæmic subjects, to find that, so long as respiration remains somewhat exaggerated in type, as, for example, from very *slight* laryngeal spasm, the pulse will be good and regular and the colour florid; whereas directly the cause of the slight obstruction in the larynx ceases to operate and the breathing falls in force and frequency, the pulse will become comparatively feeble and distinctly irregular, and the colour paler. The diastolic dilatation of the cardiac cavities, the passage of blood along the great veins into the right auricle, its circulation through the lungs, and particularly its return from the pulmonary capillaries to the pulmonary veins and left auricle, are all dependent upon efficient lung expansion. As already indicated (p. 61) breathing is largely diaphragmatic during anæsthesia, and the powerful contraction of the diaphragm is no doubt of great value in maintaining the pulmonary circulation, particularly in the bases of the lungs. Persistently shallow or obstructed breathing, intense expiratory spasm, or arrest of the respiratory pump from any cause, will, after an interval varying with other circumstances present, be followed by lividity or cyanosis, an obstructed pulmonary circulation, general venous engorgement, and, consequently, by a diminution in the quantity of blood entering the left heart. It is thus easy to understand how variations in the wrist pulse may depend upon respiration. The author is inclined to the belief that when the embarrassment to breathing is of such a nature that respiratory movements continue, although little or no air enters the chest, the abortive attempts at lung expansion still further favour the retention of venous blood within the lungs and right heart. He has notes of a case of partial laryngeal obstruction during anæsthesia, in which, with each imperfect inspiration, the wrist pulse vanished, reappearing during each expiration, clearly showing that in certain cases in which there is partial occlusion of the inlet of the respiratory pump there may be such negative pressure within the thorax during attempted inspiration that the output of blood from the lungs and heart to the great arteries is intermittently checked. Should anæsthesia be of a light type

when respiratory embarrassment occurs the circulation will hold out for a considerable time against the asphyxial strain. But should it be profound, symptoms of circulatory failure will more rapidly ensue, particularly if chloroform be the anæsthetic in use.[1]

In the next place must be mentioned the **effects of anæsthetics upon the muscular elements of the cardio-vascular system.** Recent researches indicate that in addition to the heart muscle, the muscle walls of the arterioles—particularly the arterioles of certain organs—are directly affected by anæsthetics, the effects being dependent upon the kind of anæsthetic employed and the extent to which its administration is carried. According to these researches the fall of blood pressure met with under certain anæsthetics is referable rather to direct vascular dilatation than to dilatation of central nervous origin.

As regards the influences of anæsthetics upon the **nervous elements of the circulation** our knowledge is insufficient to warrant us in making any general statements. The experimental work that has been done in this direction with each anæsthetic will be discussed in the following chapter.

With regard to the effects of **surgical procedures** upon the circulation there is good evidence to show that these effects play a more important part than is generally supposed in modifying the usual circulatory phenomena. The reflex circulatory phenomena of surgical anæsthesia and circulatory shock will be specially considered below (*vide infra* (*c*)). Closely connected with these effects must be mentioned those of cutaneous exposure, room temperature, profuse sweating, etc.

Finally, the **posture** of the subject must not be omitted as a factor, particularly in deep chloroform anæsthesia and in cases of surgical shock (pp. 129, 241).

Little is accurately known as to the changes which anæsthetic gases and vapours produce in the **blood** itself. The facts which are at our disposal will be discussed when dealing with each anæsthetic. Speaking generally, it would seem that

[1] The reader must bear in mind that these statements do not apply when certain morbid states are present.

most anæsthetics enter and leave the blood without producing in it any distinctive or important changes save those which must inevitably result from the interference with normal respiration necessarily incidental to the plan of administering anæsthetics by inhalation. When, as is the case with certain of these agents, the oxygen supply is greatly diminished or the elimination of carbonic acid is retarded, the usual effects of asphyxial blood upon the medullary centres, and upon the cardio-vascular system, will be produced. Sansom, Wittich, Böttcher, and other observers have, however, described alterations in the red corpuscles,[1] and, according to the Glasgow Committee of the British Medical Association, disintegration of these corpuscles takes place within the pulmonary capillaries during inhalation.[2] Grube urges that as urobilinuria may occur two or three days after anæsthesia, it is probable that the destruction of red corpuscles is a result rather than an accompaniment of the administration. Sherrington and Copeman have shown that in healthy animals the specific gravity of the blood commences to rise after an operation has been in progress for some little time,[3] and that the increase in specific gravity lasts for several days after the operation.

(*c*) The Nervous Phenomena of General Surgical Anæsthesia

Although anæsthetics produce their specific or characteristic effects by their action upon the nervous system, the nervous phenomena of anæsthesia belong, so to speak, to the background rather than to the foreground of an ordinary administration. At the same time, when these agents are slowly and progressively given in a diluted form, and when various stimuli are from time to time brought to bear upon the semi-anæsthetised or anæsthetised subject, the most interesting and instructive phenomena may be elicited. Speaking generally it may be said that the most highly evolved parts of the central nervous system are first affected. This is

[1] Dastre. [2] *British Medical Journal*, vol. ii., 1880.
[3] Mummery, "On Surgical Shock," *Lancet*, 18th May 1905.

true of all organisms, whether high or low in the scale of evolution. In the case of man and other mammals the cerebral cortex usually seems to be affected before any other part of the central nervous system. In all probability the basic ganglia and cerebellum are next involved. The sensory tracts and centres of the cord which connect the brain with the periphery seem next to share in the process. The cerebro-spinal motor tracts and centres are then influenced. Finally the respiratory, vaso-motor, and cardiac centres cease to act, and death ensues. It is, however, difficult to speak with anything approaching precision on these points; and it must be remembered that variations are displayed by apparently similar subjects.

Claude Bernard showed by a series of experiments on frogs that ether and chloroform primarily and chiefly affect the **sensory centres** of the cerebro-spinal axis, and that the sensibility of sensory nerve endings is destroyed, not from the action of anæsthetics upon those endings, but from their action upon the centres themselves. He pointed out, however, that as in death of sensory nerves from want of nutrition, the peripheral ends first show signs of suspended function; that the trunks are next involved; and that finally the roots share in the process. It is certain that in a large number of cases the earliest sensation experienced by a patient inhaling an anæsthetic is one of "numbness and tingling" in the extremities; and this apparently may exist without any disturbance of consciousness. Claude Bernard expressed the belief that the brain, playing the rôle of a principal nerve-centre, influenced the secondary nerve centres of the spinal cord, although it was itself incapable of being influenced by the latter. So far as the cord was concerned he held that, as in the case of sensory nerves, the function of excitability was lost from below upwards, the lumbar, dorsal, cervical, and bulbar regions being affected in the order named. In the initial stages of anæsthesia the application of traumatic or other stimuli may evoke responses which have all the appearances of, and, in one sense, are conscious responses; but owing to a want of synthesis in the sensory impressions received, and to disturbances within the perceptive centres themselves,

pain is either not appreciated as pain, or, if appreciated, is not remembered. Whilst some impairment of common sensibility is frequently met with at the outset of inhalation, typical analgesia, that is to say, the absence of the power of appreciating pain, whilst consciousness, tactile sensibility, and all other faculties are preserved, is rare; and with our present knowledge we are unfortunately unable to depend upon establishing this condition. The best results in this direction have been attained by the combined action of morphine and small quantities of chloroform (see p. 502). True analgesia is, moreover, not uncommonly observed, and particularly in feeble subjects, during recovery from deep anæsthesia. According to Dastre, the analgesia of the induction stage depends upon the sensory nuclei of the cord or cerebral ganglia being affected by the anæsthetic before the cortical centres, so that sensory impressions are blocked on their way to the perceptive areas of the cerebrum. This author suggests that this abnormal sequence of effects may be due either to diminished excitability of the hemispheres, or to increased excitability of the spinal and ganglionic sensory centres. Other physiologists, however, believe that the block takes place in the cerebral cortex.

The order in which the special senses are invaded is not precisely known. Sight is generally lost before hearing. The latter sense, indeed, may persist up to the point at which stertor commences. The author has met with one case in which the patient, a highly intelligent man, assured him that on recovery from nitrous oxide and oxygen, the sense of colour returned before appreciation of size and shape. Thus he recognised a red bowl as being red before he realised that it was a bowl and made of glass. Dastre points out, and the author can corroborate his assertion, that patients, although unconscious of their surroundings, may sometimes be made to reflexly repeat or pronounce a sequence of words. Dastre also draws special attention to the fact that before anæsthetics bring about their paralysing influence upon the various and successive parts of the nervous system, they induce a pre-paralytic state of excitement, and it thus happens that we find certain excitation phenomena belonging to the excitement stage, through

which a certain centre is passing, side by side with the paralytic phenomena of another centre. He further points out that when an equal excitation affects both the augmentor and the inhibitory parts of a nervous mechanism, it is the inhibitory or moderating influence which predominates.

Although the sensory system is primarily and fundamentally affected by anæsthetics, the motor functions are also profoundly modified. The changes, indeed, which the **motor system** undergoes in the different stages of anæsthesia are very interesting. Claude Bernard found that in the deeply anæsthetised frog motor nerves preserved their excitability. In the sciatic nerve the central terminations of the sensory filaments were anæsthetised, but not the motor filaments. In the chloroformed dog the application of vinegar to the tongue produced no salivary secretion; whereas stimulation of the chorda tympani—the secreto-motor nerve of the submaxillary gland—provoked salivation. As in the case of the sensory system, excitation phenomena first appear, to be subsequently followed by phenomena of a paralytic nature. In the earlier stages of the administration the centres capable of executing complex and co-ordinated movements are first affected. As the administration proceeds, those centres which evoke simple muscular acts falls victims to anæsthetic influence. And lastly, the automatic motor centres of respiration and of circulation fail to act and death ensues.

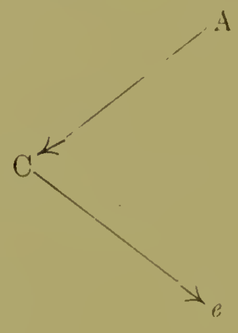
In an interesting and valuable research on the action of anæsthetics on nervous tissues, Waller has shown that the physiological power of chloroform and of ether is in the relation of 7 or 8 to 1. Chloroform is physiologically seven times as powerful as ether. This observer employed the isolated nerve as being the most convenient representative of living matter, and by means of its negative variation, evoked by stimulation at intervals of one minute, examined its behaviour to anæsthetics.

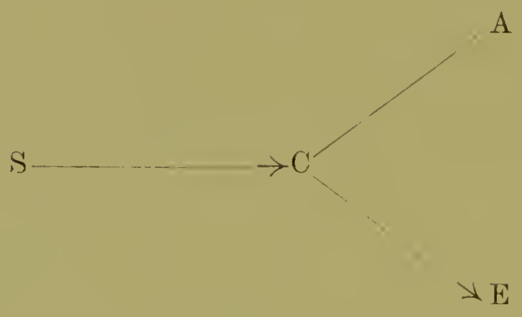
The **reflex phenomena** of general surgical anæsthesia are of great interest and importance. Their occurrence, as the result of surgical procedures, frequently transforms simple into complex anæsthesia (p. 41). Broadly speaking, reflex phenomena may arise at all stages of the administration, from

the commencement of the induction period, *i.e.* when consciousness is more or less intact, to the period immediately preceding respiratory paralysis when only certain efferent effects can be elicited.

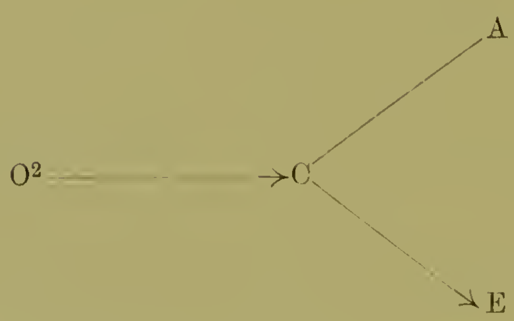
When the degree of anæsthesia is but slight, reflex responses to stimuli may have all the external characters of conscious and purposive responses, although no true consciousness or purpose is present, owing to the cerebral cortex being at the moment unable to correctly interpret the sensory stimuli which reach it. During the second stage of anæsthesia (p. 84) there is still a brisk response to most stimuli—traumatic, thermal, electric, and chemical. But as the effects of the anæsthetic increase, the reflexes vanish in a more or less definite order; so that it is possible, in practice, to maintain appropriate degrees of anæsthesia by carefully studying reflex phenomena. Patients differ considerably, however, in regard to their reflexes. Some remain passive to violent stimuli during a light anæsthesia: others display persistent reflexes in response to comparatively slight excitation during well-established narcosis. Moreover, the same patient may, during the continued administration of a properly adjusted and diluted anæsthetic vapour, *i.e.* without any noteworthy change in the supply of the anæsthetic to the nervous centres, exhibit variations in his reflexes according to the state of his nervous system at the moment. Thus, it may happen, particularly during the earlier stages of chloroformisation, when no surgical stimuli are at work, that the nervous system, including a centre (C), is in a slack, passive, and irresponsive state, so that when a certain afferent excitation (A) is brought to bear, as by touching the cornea, nothing but a small efferent effect (*e*) follows, the lids feebly closing or not at all. But if, during this condition some stimulus (S) be applied to some other part of the body, the nervous system is thrown into a state of tension and activity so that precisely the same treatment of the cornea (A) is now followed by a much more powerful efferent effect (E), the lids tightly closing. The application of an ice-cold douche to the face may have this effect. In other words, a strong stimulus may induce a state of excitability in a centre or centres so that a reflex phenomenon, which was

previously impossible, by reason of such centre or centres being inexcitable, now appears. This state of things is often met with





in the spurious chloroform sleep of children (pp. 154, 394, 400, 518). It may also be observed when two operations have to



be performed upon the same patient. Thus during the first operation (O^1) the afferent stimulus of the cornea (A) may

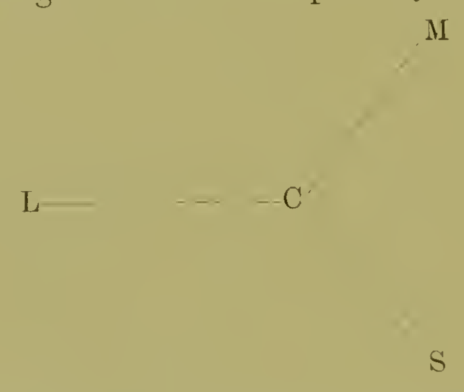
only produce a trifling effect (e). But directly the surgeon commences the second operation upon another part of the body (O^2), the degree of anæsthesia (so far as the supply and elimination of the anæsthetic are concerned) remaining the same, not only may the lids tightly close when the cornea is touched with the finger, but reflex movement of the body in response to the surgical stimulus may result. The author has also met with cases in which surgical stimuli at particular periods in the anæsthetisation have apparently inhibited and not stimulated sensory centres. For example, he has often altogether withdrawn the anæsthetic during the continuance of a surgical operation, and has observed that a slight but distinct corneal reflex, which was present at the moment of withdrawal, has *not* increased in degree, as is usual under such circumstances, but has altogether vanished for several minutes. The operations during which he has noted this interesting phenomenon have principally been intra-abdominal, and the disappearance of corneal reflex has occurred more or less simultaneously with symptoms of surgical shock. Possibly some lowering of pressure in the cerebral circulation may have produced the phenomenon. The experiments of Brown Sequard (p. 88) are noteworthy in this connection.

The **reflex respiratory phenomena** of anæsthesia are important. They are more common with certain anæsthetics than with others. They are much more common during light and moderate than during deep anæsthesia. Reference has already been made (p. 58) to the influence of psychical stimuli upon respiration. In the vast majority of cases traumatic and other stimuli augment rather than diminish the activity of the nervous mechanism of respiration. Thus, other factors remaining the same, the breathing of an anæsthetised patient who is not undergoing an operation is usually quieter, slower, and shallower than when traumatic stimuli are at work. This fact is particularly evident when, for some reason or another, a patient has been anæsthetised for a considerable time before the first incision is made: the quiet breathing at once becoming and remaining deeper in response to the cutaneous stimulation. Coughing, deglutition movements, retching, inspiratory or expiratory spasm, laryngeal spasm, and stertor

dependent upon the base of the tongue being drawn spasmodically over the laryngeal orifice, may one and all be brought about by surgical stimuli applied to parts of the body far removed from the site of the reflex phenomenon.

When reflex respiratory phenomena assume threatening proportions the condition already defined and described as **respiratory shock** will result (p. 44). In most cases the intercurrent asphyxial state thus brought about by surgical procedures is one dependent upon muscular spasm. Thus, laryngeal spasm, stertor from tongue retraction, muscular spasm about the jaws, fauces, and neck, or spasm of the thoracic or abdominal muscles may all arise reflexly and culminate in respiratory arrest. As a general rule the reflex respiratory phenomena which are capable of causing respiratory shock occur during moderate anæsthesia. When proper narcosis has been established surgical stimuli rarely affect breathing prejudicially. But as Illustrative Case No. 48 would seem to indicate, traumatic stimuli may, in rare instances, inhibit the action of the respiratory centres without causing any simultaneous circulatory effect. Primary respiratory shock, occurring as it generally does in moderate anæsthesia, is usually unattended by circulatory depression, although the latter state will necessarily follow unless breathing be quickly re-established. When the circulation begins to fail as the result of the asphyxial state which may thus be brought about by peripheral stimuli, the condition which has been called composite shock (p. 44) will result.

It is interesting to note that respiratory conditions brought



about reflexly will often vanish reflexly. Thus, let us suppose that a moderately deeply anæsthetised patient is undergoing an

operation, and that at a particular juncture swallowing movements or laryngeal spasm (S) are being excited by the surgical manipulation (M). As a result of this there is necessarily some temporary interference with the air supply to the lungs, and hence some degree of cyanosis. By briskly rubbing the lips (L) with a cloth the reflex act (MCS) is at once inhibited, the air-way is again rendered patent, respiration recommences and cyanosis disappears. Lip friction is thus often exceedingly valuable, not only in restoring free breathing but in preventing the vomiting which so often follows deglutition.

Reflex circulatory phenomena are very common during general surgical anæsthesia; but they are more difficult to differentiate from one another than reflex respiratory phenomena. Reference has already been made (p. 63) to the influence of psychical stimuli upon the circulation. Reflex circulatory phenomena differ in their incidence and intensity according to numerous circumstances, such as the kind of anæsthetic in use, the degree to which its administration has been carried, the nature, situation, and intensity of the stimulus, the state of the vaso-motor, the cardio-inhibitory, and the cardio-accelerator centres, and the character of the discharges from those centres. The existence of two varieties of vaso-motor nerves—those the stimulation of which causes constrictor effects, and those the stimulation of which causes dilator effects—is well borne out by a study of the reflex phenomena of anæsthesia. Crile, whose work on circulatory shock is considered below, found that the excitation of sensory nerve fibres as by traumatic stimuli caused either a rise or fall in general blood-pressure according to the particular nerve mechanism which was affected, the stimulation of pressor nerves causing vaso-constriction and a rise in blood-pressure, and of depressor nerves vaso-dilatation and a fall of blood-pressure. Mechanical stimulation of sensory nerves, when both the animal and the nerve were fresh, at first produced pressor effects; but with the continuance of the stimulus these generally lessened and were then replaced by depressor effects. After repeated stimulation of the same nerve or of several nerves the animal passed into a state in which no stimulation even of a fresh nerve trunk would produce a rise in blood-pressure. Pressor action seemed to be brought out by first

or early stimulation and to be more readily exhausted than depressor action. We find, clinically, that reflex circulatory phenomena are much more common with chloroform than with ether. They may occur at all stages of the administration, but they are chiefly of importance during profound narcosis.

We now come to the consideration of **circulatory shock.** It is difficult to speak with certainty as to the precise circulatory effects which may take place in human beings, when operations are commenced during semi-consciousness. Prior to the introduction of anæsthetics deaths were not uncommon at the moment of the commencement of an operation; and it is therefore not unreasonable to suppose that if an operation be begun before consciousness has been completely destroyed the risk of such an accident will still remain. It is possible that the respiratory and circulatory disturbances, which, as we have seen (pp. 58 and 63), may arise from the dread of an impending operation, predispose to sudden syncope from surgical stimuli applied before consciousness has been annulled, death taking place from cardiac inhibition, vaso-motor paralysis, or both these conditions combined.

When the administration of an anæsthetic has been carried to that point at which pain can no longer be felt, the commencement of a surgical operation is probably unattended by any risk of primary and fatal reflex syncope. From this point onwards to the point at which the corneal reflexes vanish and the muscular system relaxes, surgical procedures may produce primarily circulatory effects, but these are not, as a rule, of importance. But when once profound anæsthesia has become established, and particularly when chloroform has been used, certain surgical stimuli are capable of producing very marked effects upon the general circulation. This is undoubtedly due to the fact that, in deep chloroform anæsthesia, the blood-pressure is already low from toxic dilatation of the cardio-vascular musculature, so that the effects of reflex vaso-motor dilatation or of reflex cardiac inhibition, which would not have been obvious had the blood-pressure been high, now become exceedingly obvious and circulatory shock results. This form of shock has been exhaustively studied by

Crile.[1] According to this observer the condition is essentially one of impairment or paralysis of the vaso-motor mechanism, and consequent fall of general blood-pressure, brought about by violent stimulation of sensory or sympathetic nerves, the shock being usually proportional to the area of nervous tissue involved. That blood tends to accumulate in the splanchnic area during circulatory shock was indicated by a rise in pressure in a water manometer placed in the splenic vein with its cannula pointing towards the heart. Whilst the central pressure was falling, as the result of the shock, the portal pressure was rising owing to an increase of blood in the latter area. When the arteries of the splanchnic area were clamped before opening the abdomen, exposure and manipulation of the intestines failed to produce shock. It seems a little doubtful whether this splanchnic shock is entirely referable to an effect upon the *main* vaso-motor centre. In certain cases of shock Crile found the vaso-motor paralysis complicated by respiratory or cardiac depression or by hæmorrhage. He observed, moreover, that in profound shock the usual physiological vascular compensation in change of posture was lost. Excitation of the peritoneum caused a rapid dilatation of the vessels of the mesentery and of the hollow viscera. That cardiac depression is not an essential factor in shock was shown by the fact that if the blood-pressure were artificially raised in an animal apparently dead from shock the heart again began to beat, showing that fatigue of the heart muscle was not present. Crile also found that he could obtain cardio-inhibitory effects in an animal apparently dead from shock, showing that the cardio-inhibitory centre was still intact; while the fact that the heart remained rapid till death seemed to prove that the cardio-accelerator centre was also unimpaired. Circulatory shock was still produced in an animal whose heart had been isolated from the nervous system by severing both vagi and both accelerantes. That the shock was not due to exhaustion of the peripheral neuro-vascular mechanism was shown by the fact that when the vagi and accelerantes were divided, curare given, and artificial respiration

[1] "Surgical Shock," by G. W. Crile, A.M., M.D. See also Boston *Med. and Surg. Journ.*, March 1903.

maintained, adrenalin caused the fallen blood-pressure to return to even a higher point than the normal. Moreover, the usual rise in blood-pressure on stimulation of the sciatic was not observed in shock, showing that the vaso-motor centre was paralysed. Corroboration of this view was also afforded by the observation that by cocainising the centre or dividing the cord just below the medulla all the phenomena of circulatory shock were produced. Omental irritation usually caused a rise in general blood-pressure. Mechanical injury to the kidney caused no marked effect except when the peritoneum was involved. Whilst traumatic stimulation of the bladder generally caused a rise in blood-pressure, injury or manipulation of the testes usually caused a fall. Crile found that shock occurred in direct proportion to the nerve supply of the part involved. Cocainisation of the main afferent nerve trunks prior to injury prevented shock, however severe the injury, by stopping afferent nerve impulses on their way to the brain. Injection of a 2% solution of cocaine into the medulla produced shock and stopped respiration, the shock persisting during the subsequent artificial respiration. It is probable that in circulatory shock, the superficial vessels are contracted owing to the greatly diminished quantity of blood reaching them. Clinically we find that this condition develops more rapidly under chloroform than under ether, owing, no doubt, to the fact that the former anæsthetic invariably causes a fall of blood-pressure of its own, independently of any surgical procedure[1] (p. 128).

When circulatory shock is very pronounced, respiration may become feeble, or cease, owing to diminished cerebral blood supply. In this way composite surgical shock (p. 44), characterised by suspension of both circulation and respiration, may arise.

The clinical aspects of all these varieties of surgical shock are discussed in Chap. VIII. (p. 250), Chap. XVIII. (p. 537), and Chap. XIX. (p. 575).

The corneal, laryngeal, pharyngeal, rectal, vesical, peritoneal,

[1] For further information the reader is referred to Mr. J. P. Lockhart Mummery's interesting and carefully reasoned lectures on "The Physiology and Treatment of Surgical Shock and Collapse," *Lancet*, 18th March 1905, p. 696.

and genital reflexes, *i.e.* reflex muscular contraction when any of these parts are stimulated, are amongst the latest to disappear. In dogs the patellar reflex is at first exaggerated; it then lessens and finally disappears before the corneal reflex vanishes. The spinal cord undoubtedly preserves its power of transmitting sensory impulses till the very last; for certain stimuli may evoke reflex effects (particularly upon respiration) even when a very profound narcosis is present. It is difficult to say with certainty at what particular point in the course of anæsthesia the main vaso-motor centre becomes paralysed, but it is probable that, in the absence of surgical or other stimuli capable of disorganising its action, it retains its controlling function till quite late. According to Richet stimulation of the vagus will slow or even arrest the heart movements in all stages of anæsthesia. It is difficult, however, to produce a fatal result by vagal stimulation. Brodie and Russell[1] found that the pulmonary fibres of the vagus produced the most marked inhibition, the cardiac branches being much less effective, whilst those below the pulmonary were still less active. According to these observers the connection of the respiratory tract with the cardio-inhibitory centre is very close. As to the respiratory centre itself, it appears to remain sensitive to certain stimuli till just before its automatism is finally abolished. If the vagi be divided during deep anæsthesia, the usual respiratory phenomena still appear.

[(*d*) The Muscular Phenomena of General Surgical Anæsthesia

The muscular system is capable of being affected both directly and indirectly by general anæsthetics. Little is definitely known as to the *direct* effects of these substances upon muscle. Claude Bernard found that the application of etherised or chloroformed water to muscles induced rigidity and loss of sensibility, and that cloudy changes appeared microscopically. Ringer's experiments with regard to the action of anæsthetics upon the muscular tissue of the frog's heart will be subsequently considered; whilst those of

[1] *Journ. Phys.*, vol. xxvi. p. 92.

Sherrington and Sowton on the dosage of the mammalian heart by chloroform will also be referred to. It would seem that when muscles are subjected to anæsthetic action, they gradually lose their power of responding to stimuli. Thus, when the peripheral end of the sciatic nerve is stimulated during the administration of chloroform, a progressive diminution in the work done by the muscle takes place, the diminution becoming more marked as the duration of anæsthesia increases (Dastre). Most of the muscular phenomena of anæsthesia are dependent upon *indirect* (nervous) action. The following muscular phenomena may be witnessed in human subjects during the inhalation of anæsthetics :—

(1) **Conscious voluntary movements**, such as adjusting the head to a comfortable position, crossing the legs, etc. These may or may not be associated with some degree of analgesia.

(2) **Uncontrollable "nervous" movements**, such as tremor, hysterical outbursts, etc.

(3) **Sub-conscious purposive movements.** These are often very interesting. A patient may, for example, attempt to remove a mouth-prop placed between his teeth under the impression that it is a pipe or cigar. A movement originally initiated during normal consciousness may become greatly exaggerated as will-power lessens. Hardly noticeable movements of the feet may, for example, gradually increase to uncontrollable stamping.

(4) **Unconscious excitement or intoxication movements.** These may vary from the simple laughter of intoxication to the most violent maniacal excitement.

(5) **Simple tonic spasm.** This may be local or general, and may occur in all stages of anæsthesia. It is usually referable either to a surgical stimulus, to some irritant within the air-tract, or to diminished air supply.

(6) **Clonic spasm.** This may occur with all the usual anæsthetics ; it is, however, most common with pure nitrous oxide. With this agent clonic movement is, as the writer has shown, of anoxæmic origin ; and there is reason to believe that even with other anæsthetics such movement is often of a similar nature. Clonic movements may affect the arms, hands, legs, feet, trunk or neck. To the more violent spasm, such as

is seen with pure nitrous oxide, the term "jactitation" is applied. The author has sometimes observed, in patients under chloroform, twitchings of the fingers suggestive of the movements in piano-playing, and believes them to be usually dependent upon some slight inadequacy in the air-supply. Thus he has seen them come and go in obedience to the kind of breathing which he has made the unconscious patient adopt. They have appeared with imperfectly nasal breathing, and have disappeared with free oral breathing. Other convulsive twitchings may take place under chloroform (p. 393). Paul Bert[1] found that when an animal was anæsthetised and then submerged, asphyxial convulsions were still produced, although they were less marked than when asphyxia was brought about in the non-anæsthetised state. Convulsive phenomena are sometimes witnessed when a poisonous quantity of chloroform has been swallowed (Taylor).

(7) **Slow, co-ordinated movements**, particularly of the fingers, hands, and arms, sometimes occur in deep anæsthesia. Their nature is unknown (see p. 398).

(8) **Fine tremor** of the legs, arms, or whole body is sometimes met with in moderately deep anæsthesia, especially under ether.

It is difficult to say what particular parts of the central nervous system are involved in the development of the muscular phenomena just described. As regards the disorderly and convulsive movements of the early stages of anæsthesia, Duret attributes them to excitation of the psycho-motor centres; whilst Dastre considers them to be caused by excitation of the bulbo-spinal sensory tracts. As already indicated, many of the muscular phenomena of anæsthesia are in reality asphyxial, or more properly anoxæmic in their origin. According to some physiologists, the medulla oblongata at its junction with the pons contains what is known as a "spasm centre." When this centre is irritated, as by sudden venosity of the blood, or by sudden anæmia of the medulla, general convulsions occur. The clonic phenomena of nitrous oxide anæsthesia would thus be explained.

[1] *Acad. des Sciences*, 18th March 1867.

(*e*) The Effects of General Anæsthetics upon the Glandular System

Different anæsthetics produce different effects upon the various glandular organs of the body, and these effects will also be found to vary according to the particular stage of anæsthetisation. There is usually, for example, a more copious secretion from the mucous, the salivary, and the sweat glands under ether than under chloroform. The author has noticed that when intercurrent surgical shock takes place the mucous secretion of the mouth is suspended, reappearing as the shock subsides. The sweat glands, on the other hand, are active during surgical shock, the "cold sweat" being replaced by a warm and dry skin as the circulation becomes re-established.

The effects produced by anæsthetics upon the **kidneys** and their secretion will depend upon such circumstances as the kind of anæsthetic employed, the method adopted for its administration, the degree to which the administration has been carried, the presence or absence of shock, and other factors which, in the present state of our knowledge, hardly admit of enumeration. The most recent researches [1] seem to indicate that with both ether and chloroform, there is an increase in urinary secretion up to the point at which surgical anæsthesia (loss of corneal reflex) occurs; that during full narcosis urinary secretion is more or less completely arrested; and that during the recovery period the renal functions are resumed and urine is again secreted. In the case of dogs there is said to be a period of hyperactivity of the renal functions after the withdrawal of the anæsthetic. For further remarks upon this subject the reader is referred to the following chapter in which will be discussed the special effects of ether and chloroform upon the kidneys, and to the clinical section of the work in which the various after-effects of these and other anæsthetics are considered.

[1] See Prof. W. H. Thompson's article, *Brit. Med. Journ.*, 25th Mar. 1905, p. 649; also a paper by Drs. H. Pringle, Maunsell, and S. Pringle, *Brit. Med. Journ.*, 9th Sep. 1905, p. 542.

D. DEGREES OR STAGES OF ANÆSTHESIA

By carefully studying the effects produced by anæsthetics upon man, observers have from time to time proposed to speak of different **degrees or stages** in their action. Thus Snow states that Flourens recognised four stages. In the first of these there was paralysis of cerebral functions; in the second, paralysis of cerebellar functions; in the third, paralysis of the functions of the spinal cord; and in the fourth, paralysis of the functions of the medulla oblongata.

Snow spoke of five degrees.[1] In the first of these consciousness was not abolished; there were various disturbances of special senses, and some diminution of common sensibility. In the second the mental functions were impaired but not necessarily suspended; there were laughing, talking, and excitement. In the third, voluntary motion was suspended, but involuntary movements continued; rigidity and spasm occurred, muttering was common, and although there was no consciousness or perception of pain, the subject might cry out during a surgical procedure. In the fourth, the breathing became stertorous, the pupils dilated, and the muscular system relaxed. In the fifth and last degree the breathing became difficult, feeble, or irregular, and was sometimes performed only by the diaphragm; respiration then ceased, and the heart, which for a time pulsated distinctly, soon failed as in death from asphyxia.[2]

Dastre[3] describes four periods: (1) suspension of brain functions—hence sleep; (2) abolition of functions of spinal cord considered as a conducting organ of sensibility—hence complete anæsthesia; (3) abolition of motor functions of cord; and (4) bulbar paralysis—cessation of respiration and circulation. The objection to Dastre's classification is that there is good evidence to show that even in deep anæsthesia both sensory and motor impulses may be transmitted by the cord.

Taking all circumstances into consideration we may conveniently speak of the following degrees or stages in simple general surgical anæsthesia (p. 41):—

[1] *Op. cit.* p. 35.

[2] As we shall presently see (p. 122), Snow also believed that *with concentrated chloroform atmospheres* the heart might cease before respiration.

[3] *Op. cit.*

TABLE showing the degrees or stages in the action of the chief general anæsthetics upon the human organism, and the phenomena which usually characterise these stages when no complication, asphyxial or traumatic, is present.

Degree or Stage.	Effects.
1. Stage of analgesia.	Excessive ideation; disturbances of judgment, control, and volition. Analgesia. Vertigo and loss of power of maintaining equilibrium. Pleasurable or distressing sensations. Disturbances (exaggeration or diminution) of common sensibility and of special senses. Misinterpretation of external impressions. Emotional disturbances, *e.g.* laughter and crying. Reflexes well marked and often exaggerated; sensory stimuli produce co-ordinated and apparently purposive movements. Loss of power of remembering (fixing) sensory impressions. Dreams. Rise of blood-pressure and increase of cardiac action. Respiration increased but regular and free, unless interfered with by emotional causes or by direct irritation of anæsthetic, inducing cough, "holding of breath," deglutition movements, retching, or vomiting. Pupils dilated.
2. Stage of light anæsthesia.	Complete loss of consciousness. Delirium; articulate speech passing into unintelligible muttering. Respiration still deeper and quicker than normal; often irregular and impeded by General tonic muscular spasm, deglutition, closure of glottis, spasm of jaws, etc. Clonic muscular spasm. Reflexes still persist; but motor results of stimuli devoid of purposive character. Inarticulate phonated (expiratory) sounds. Coughing, retching, vomiting. Heart's action still excited (much dependent on character of breathing). Pupils smaller.
3. Stage of deep anæsthesia or narcosis.	Relaxation of most muscles. Breathing regular, often softly snoring or stertorous. Decrease of respiratory exchanges; fall of temperature. Increasing fall of blood-pressure (chloroform). Heart's action weakened, variable degree of cardiac dilatation. Loss of corneal, pharyngeal, laryngeal, patellar, and most but not all reflexes. Pupils larger.

TABLE—*continued*

Degree or Stage.	Effects.
4. **Stage of bulbar paralysis.**	Loss of bladder distention, rectal, and other very late (*e.g.* certain peritoneal) reflexes. Breathing becomes shallow. Increasing lividity or pallor. Breathing ceases (paralysis of respiratory centres), loss of respiratory reflexes. Paralysis of vaso-motor centres (?). Feeble, irregular cardiac action; complete cardio-vascular paralysis. Widely dilated pupils. Separation of eyelids. Death.

The above table is only intended to indicate in a general sense the order in which the various effects produced by anæsthetics make their appearance. As already mentioned, there are so many factors capable of modifying the course of anæsthesia that it is exceedingly difficult, if not impossible, to generalise.

E. ON THE INTIMATE PHYSIOLOGY AND CHEMISTRY OF GENERAL SURGICAL ANÆSTHESIA

Athough many of the problems which have for years surrounded the subject of anæsthesia may now be regarded as solved, there remains one problem which has hitherto defied all attempts at solution, viz. the nature of the changes within the central nervous system which are capable of bringing about a state of general anæsthesia. As we have seen, this state may be induced by a variety of therapeutic agents; but it may also be established, in a more or less complete and typical form, in numerous other ways.

There is, in natural sleep, some degree of anæsthesia; the degree varying in different subjects, and in the same subject according to the special circumstances which may be present. The auditory, olfactory, visual, and tactile stimuli which will arouse one person may not even disturb the slumbers of another. But apart from the question of anæsthesia, there are several other interesting points of similarity between natural

and artificial sleep. Thus we find in regard to both states that a rapid flow of confused ideas immediately precedes unconsciousness; that vivid dreams, dependent upon some suggestion or incident prior to unconsciousness, are remembered on awakening;[1] that the muscular system is relaxed; that complicated reflex phenomena may be elicited; that the eyelids are closed; that the pupils are, as a rule, contracted;[2] that the production of heat is reduced; that the exhalation of carbonic acid is diminished; and that respiration is often snoring or stertorous in character. It has also been urged that both in natural and in artificial sleep cerebral anæmia is present; but whilst it is undoubtedly true that in the former state a general fall of arterial tension occurs, and that as a consequence of this the blood supply to the brain becomes reduced, the analogy only holds good so far as *chloroform* anæsthesia is concerned. With nitrous oxide and with ether no such fall in pressure takes place, and the blood supply to the brain is therefore not lessened. The similarities between natural and artificially induced sleep are most striking when we compare heavy natural sleep with the state of "false anæsthesia" or "chloroform-sleep" (pp. 72, 154, 394, 400). It is not, indeed, beyond the limits of possibility that future research may indicate that a similar change within the elements of the cerebral cortex is responsible, at all events in part, for the phenomena of both states. At the present time little if anything is definitely known as to the nature of the physiological changes which are involved in the production of sleep; but the existence of the analogies here referred to may perhaps be taken to support the view that this state is dependent upon the presence within the circulation of some chemical substance capable of exerting, in association with other factors, temporary soporific influences. Such a view, however, is by no means generally accepted; for, according to the most recent hypothesis,[3] the unconsciousness

[1] This is only true as regards very short administrations of anæsthetics.

[2] As regards the pupils, the analogy only holds good when we compare the sleeping subject with the anæsthetised patient who is allowed to remain free from all traumatic and other stimuli, and who is, moreover, free from all intercurrent asphyxial conditions.

[3] For many interesting points in connection with sleep I am indebted to Dr. Bradbury's lectures. See *Lancet*, 24th June 1899, p. 1685.

of natural slumber is to be regarded as resulting not so much from changes induced by this or that agent or agency within the "neurons" and other structures which collectively constitute the independent elements of the nervous system, but from simple alterations of a histological character affecting the dendritic processes which connect individual neurons one with another. According to some authors a retraction of these processes takes place, with the result that the individual neurons become isolated (Lépine and Duval), whilst according to others a widening in these communicating paths occurs, so that nervous impulses more readily travel from one cell system to another (Lugaro). If we adopt the former view, then the isolation of independent cell systems is to be regarded as the immediate cause of sleep; whilst according to the latter the widening of impulse-paths is to be looked upon as responsible —such widening leading to confusion of thought and finally to unconsciousness. It is an interesting fact that it is frequently possible, by very gradually administering chloroform during sleep, to make the natural pass into the artificial state (p. 400). Natural sleep or a feeling of drowsiness is, moreover, a common sequel of anæsthetisation. The peculiar movements of paralysis agitans cease during general anæsthesia just as they cease during natural sleep.[1]

Extremes of temperature are capable of materially modifying, and, under certain circumstances, destroying normal consciousness. Claude Bernard showed that when frogs were submitted to a temperature of 0° C. anæsthesia resulted; as the temperature rose, vitality returned; as 30° to 35° was reached, vitality again lessened; at about 37° anæsthesia again supervened; and at 40° the animal died. Richet[2] obtained similiar results with lobsters. He found, however, that rabbits, when exposed to intense cold, still remained sensitive to traumatic excitation, but they reacted slowly. Spontaneous movements were the first to become affected; then reflex functions were suspended; and, finally, muscular relaxation took place. Claude Bernard believed that in cold-blooded animals an increase in temperature induced an

[1] I have observed this not only with chloroform but with nitrous oxide and oxygen.

[2] *Dict. de Physiologie.*

asphyxial state of the blood, and that it was this altered state which led to anaesthesia.

Brown-Séquard has shown that in the lower animals certain peripheral stimuli may induce a generalised anæsthetic effect. Thus, by applying electrical excitation to the larynx or its nerves, he was able to bring about a state which he regarded as one of general anæsthesia; and a similar result occurred when a forcible stream of carbonic acid gas was projected into the back of the mouth or into the larynx itself. It is also stated that the local application of chloroform or chloral to certain skin areas of the cat induced generalised effects of a similar nature. These curious phenomena have usually been ascribed to nervous inhibition, brought about by the violent excitation of certain sensory areas; but the subject requires further study before any definite opinion can be expressed concerning it.

It has been shown by Bonwill that it is possible, with certain subjects, to induce a state of analgesia or (?) anæsthesia by the simple expedient of rapid and deep breathing. Dental operations have thus been painlessly performed; but the method has, in other hands, proved uncertain, whilst its *modus operandi* has yet to be established. Some have explained the phenomena by supposing that the exaggerated respiration so modifies the cerebral circulation that the normal activity of the intellectual and perceptive centres becomes temporarily suspended. It is possible, however, that "suggestion" or "inhibition" may play a part in some cases, whilst simple nervous exhaustion may constitute a factor in others.

The analgesic and anæsthetic effects produced by hypnotism hardly admit of discussion in the present work. Experience has shown that only certain susceptible persons can be thus influenced, that a long education is needed to render subjects hypnotisable, and that the general health of those who submit themselves to this treatment is liable to become seriously injured.[1]

Claude Bernard fully realised the occasional presence of an asphyxial element in ordinary cases of chloroformisation, and

[1] For a good example of results that may be achieved under favourable circumstances see *Lancet*, p. 527, 22nd August, 1903.

threw out the suggestion that asphyxia was probably capable of producing an anæsthesia of its own—a suggestion which is of interest when considered in the light of more recent research. According to Reboul and Morat,[1] frogs placed *in vacuo*, or in an inert gas, become immobile and insensible; reflex movements disappear; respiration then ceases; but circulation persists for a considerable time. Pure nitrogen rapidly destroys consciousness and produces complete insensibility to pain; and mixtures of this gas with small proportions of oxygen (up to 7 per cent) are similarly capable of inducing anæsthesia, the rapidity of action diminishing as the oxygen percentage rises (see p. 456). It is noteworthy that these results occur when every provision is made for the escape of carbonic acid gas from the lungs, so that we are justified in regarding them as due simply to anoxæmia or want of a sufficiency of oxygen to carry on normal metabolism within the nervous centres. Nitrous oxide produces very similar effects, but they come about with somewhat greater rapidity and are more persistent—a difference doubtless dependent upon the greater solubility of this gas. With both nitrogen and nitrous oxide the muscular system is thrown into an epileptiform or tetanic state; and it is this factor which renders these gases irrespirable when administered in a state of purity. The anoxæmic anæsthesia which we see in its typical and pure form in the case of nitrogen and hydrogen is also met with as a by-product, so to speak, when ether, chloroform, or other agents are being employed; and the intensity of the effects produced by these drugs is, in practice, often largely dependent upon the degree of anoxæmia present (see p. 336). In addition, however, to the simple limitation or deprivation of oxygen thus favouring or actually producing general anæsthesia, there is ample proof that, in certain methods of anæsthetisation in which re-breathing is permitted, the presence of carbonic acid gas (itself an anæsthetic) may contribute to the narcosis.

Claude Bernard asserted that anæsthetics brought about within the central nervous system changes which were similar in many respects to those produced either by interference with the blood supply or by commencing natural death. He

[1] Dastre, *op. cit.*

urged that although there were different means for inducing anæsthesia, they all led to the same modifications in the nerve-cells, whatever these modifications might be. He went, indeed, a step further than this, and believed that a process of semi-coagulation took place within the cell-contents of nerve-centres, such semi-coagulation resulting from the direct effects of the anæsthetic brought thither by the circulating blood. Directly elimination of the anæsthetic took place, this coagulative process began to subside, and eventually the cell-contents resumed their normal character. In favour of this theory there was the fact, already alluded to, that muscular tissue, and indeed all protoplasmic matter, quickly becomes cloudy and eventually coagulated when exposed to water containing ether or chloroform in solution. Some observers have found, in animals killed by chloroform, a marked disappearance of fat globules from nerve-cells; and it is pointed out by Meyer and Baum [1] that all bodies which are nearly chemically indifferent have an anæsthetic action if they are soluble in fat, provided they can penetrate to the cells of the brain. But considering that nitrous oxide, which has no fat-dissolving properties, produces effects almost identical in their main features with those produced by chloroform, this hypothesis has little to recommend it. According to Lauder Brunton,[2] chloroform is a powerful solvent of protagon, "the essential ingredient both of the nerve-centres, of the nerves themselves, and of the red blood corpuscles"; but it is very doubtful whether this chemical fact has any important bearing upon the physiology of anæsthetic action. It has been suggested that anæsthetics may exert a dehydrating effect upon protoplasm (Dubois' theory); but the grounds for this assumption are too slender to warrant serious consideration.

Richet [3] contended that a temporary and dissociable combination was produced between the anæsthetic and the protoplasmic matter with which it came in contact; and this view has received support from recent researches. Thus Moore and Roaf conclude, as the result of numerous experiments,[4] that anæsthetics form unstable compounds or aggregates

[1] See Dr. Bradbury's paper. [2] *Therapeutics*, p. 796. [3] *Dict. de Physiologie.*
[4] *Proc. Roy. Soc.*, vol. lxxvii. Series B, No. B 515, p. 86.

with the proteids of the tissue cells; that anæsthesia is due to a paralysis of the chemical activities of the protoplasm as the result of the formation of such aggregations; and that the compounds so formed are unstable and remain formed only so long as the pressure of the anæsthetic in the blood is maintained. They find, moreover, that the solubility of all the anæsthetics with which they experimented is higher in serum than in water; that at a certain concentration, definite for each anæsthetic, there occurs opalescence and commencing precipitation of proteid; that at equal concentration of chloroform in water or saline on the one hand, and serum, hæmoglobin, or the tissues (brain, heart, muscle, and liver) on the other, the vapour-pressure is always higher in the former than in the latter; and that accompanying the combination of the anæsthetic with the proteid there takes place a splitting off of electrolytes. Hamilton Wright[1] in a recent research maintains that ether and chloroform produce bio-chemical changes within the central nervous system, the nerve-cells of both brain and spinal cord undergoing "rarefaction," or, in extreme cases, "pseudo-degeneration," whilst the tips and stems of the chief dendritic extensions of many pyramidal cells display early and constant moniliform enlargements. He states that these enlargements increase in size during anæsthetisation and spread along the dendrons of the cell body. The nervous structures of rabbits are more easily affected than those of dogs. He ascribes the moniliform swellings observed in the dendrons to the effects of the anæsthetic upon the Nissl's bodies within the cells, believing, in common with many other observers, that these bodies possess nutritional and energy-producing functions.

In attempting to summarise this portion of our subject, all we can say is that general anæsthesia is probably brought about by some change of a physico-chemical character within the protoplasm of nerve-cells; that the most delicate and vulnerable of the nervous elements—those which give to the organism its characteristic peculiarities, attributes, and functions—are first affected; and that, finally, the most resistant centres,

[1] "The Action of Ether and Chloroform on the Neurons of Rabbits and Dogs," *Journ. Phys.*, vol. xxvi. pp. 30, 362.

upon which life is dependent, are attacked. Whether this change is due to the local effect of the anæsthetic itself upon the cell-contents, or whether some alteration in the blood produced by the anæsthetic is the immediate cause of such changes, it is at present impossible to say. As is pointed out in many parts of this work, there are remarkable analogies between the effects of simple anoxæmia and those produced by general anæsthetics, and it is not at all improbable that future experimental research may lead us to the conclusion that general anæsthetics produce their characteristic effect by limiting the normal processes of oxidation upon which the intellectual, sensory, and motor centres depend for the execution of their respective functions. It would be interesting to ascertain whether, during anæsthesia induced by nitrogen, changes similar to those described by Hamilton Wright (*vide supra*) are to be detected within the central nervous system.

F. THE AFTER-EFFECTS OF GENERAL ANÆSTHESIA

After the withdrawal of an anæsthetic the animal which has been subjected to its influence generally recovers its vital functions without the supervention of any injurious after-effects. This is conspicuously the case with such anæsthetics as nitrous oxide and those of the ethyl-chloride and ethyl-bromide type which are rapidly eliminated. The prolonged administration of ether, however, not unfrequently leads to fatal **lung complications**; whilst protracted anæsthetisation by chloroform, or the repeated administration of this agent, is liable to be followed by **degenerative visceral changes.** After-effects of the last mentioned variety have been described by numerous observers. In 1866 Nothnagel[1] showed that fatty degeneration of the liver and heart followed the introduction of chloroform into the stomach or subcutaneous tissues of rabbits. In the subcutaneous injections fatty degeneration of the kidneys was also produced, and the urine was found to contain blood corpuscles and casts. He concluded that chloroform produced fatty degeneration by destroying the blood corpuscles, and compared its action with

[1] Berlin, *Klin. Woch.* 1866, No. 4.

that of the bile acids, arsenic, and phosphorous. Ether produced only a very slight fatty change. Ungar and Junker[1] appear to have been the first to demonstrate in animals the fatty changes produced by chloroform when administered by inhalation. In dogs extensive changes of this nature were met with in the liver, heart, and voluntary muscles some hours after a single prolonged inhalation. Repeated administrations were followed by fatty degeneration in the kidneys, spleen, and mucous membranes of the respiratory and alimentary tracts, in addition to changes in the liver and heart. Strassmann has confirmed the observations of Ungar, and has shown that chloroform causes an increased excretion of nitrogen in starved animals, thus pointing to the increased destruction of proteids. Loss of blood before chloroformisation intensified the degenerative effects produced by the drug. In 1889 Ostertag also confirmed Ungar's observations. The results of chloroforming several animals for an hour or so at a time during a period of many days are thus summed up by Ostertag:[2] (1) The presence of "Fatty degeneration of organs, especially fatty infiltration of the liver, and fatty metamorphosis of the cardiac and skeletal muscles, kidneys, and stomach; (2) these fatty changes result from the action of chloroform upon the blood (destruction of red corpuscles) and upon the tissue cells; (3) some individuals have a greater susceptibility to this action of chloroform, and succumb at an earlier period to its effects; and (4) the fatal effect is due to cardiac paralysis which may occasionally be accompanied by but slight anatomical lesions of the myocardium, and also the general carbonisation of the blood." More recently these experiments on animals have been corroborated by Heintz, by Bandler, and by Ferdinand Schenk[3] who examined the livers of animals before and some days or weeks subsequent to chloroform narcosis, and found that the fat which appeared in the organs a few hours after inhalation sometimes did not disappear for days or even weeks. Ether gave rise to similar but less marked changes. In a still more recent experimental research on the poisonous effects of

[1] For this and other references I am indebted to the writings of Stiles and M'Donald (*Scottish Medical and Surg. Journal*, Aug. 1904).

[2] I am indebted to Dr. L. Guthrie for this information.

[3] Guthrie, *Lancet*, 6th July 1903.

chloroform upon the kidneys Offergeld found[1] that animals chloroformed for a long time (up to two hours) recovered well from the immediate effects of the anæsthetic, but on the second and subsequent days they became lethargic, and in from 48 to 60 hours they died. Post-mortem examinations of rabbits and guinea pigs thus killed by a single administration showed **parenchymatous degenerations in the heart, liver, and kidneys.** Fatty degeneration of the kidney did not occur in the organ which had had its arterial supply cut off by ligature of the renal artery after 40 minutes anæsthesia; but pronounced degeneration of the kidney occurred after ligature of the renal vein and an anæsthesia of 30 minutes. Offergeld came to the conclusion that in these cases of **postponed chloroform death** the fatal result was due to the effect of the drug on the kidney cells. He found that a mixture of chloroform and oxgyen was less likely to induce these changes than one of chloroform and air. These conclusions are interesting in their relation to those of Beesly (p. 609) and others, who attribute the fatalities from so-called "**acid intoxication**" after general anæsthesia (pp 604 *et seq.*) to the inability of the kidneys to eliminate the fatty acids and acetone upon whose toxic action this "acid intoxication" is believed to depend.

[1] Quoted by Bevan and Favill (*Journ. of Amer. Med. Assoc.*, 2nd Sept. 1905, p. 691).

CHAPTER IV

THE THEORETICAL AND EXPERIMENTAL PHYSIOLOGY OF GENERAL SURGICAL ANÆSTHESIA (*continued*)

PART II.—SPECIAL PHYSIOLOGY

A. NITROUS OXIDE

Humphry Davy believed that nitrous oxide was decomposed into its constituent elements during its passage through the circulation. The intoxicating effects which the gas produced were hence ascribed to hyper-oxygenation of the blood, whilst the anæsthetic effects were explained on the assumption that the over-production of oxygen led to the formation of such quantities of carbonic acid that "internal asphyxia" arose. It soon became clear, however, that nitrous oxide was too stable a body to be decomposed at the temperature of the blood; and Frankland,[1] who analysed the expiratory products of several administrations, failed to find any distinct evidence of decomposition. In 1864 Hermann[2] came to the conclusion that nitrous oxide was simply absorbed by blood plasma, that it produced no change in blood, and that it was not itself altered during its period of association with blood. Hermann found that 100 volumes of blood at the temperature of the body absorbed somewhat less than 60 volumes of nitrous oxide. Several years later, Bert fixed the solubility at 45 volumes of gas per 100 volumes of blood. The hyper-oxygenation theory was therefore abandoned, and a precisely opposite hypothesis took the field. It was now maintained, and particularly by Jolyet, Blanche, and Duret, that the anæsthetic

[1] *St. Bartholomew's Hospital Reports*, vol. v.
[2] *Brit. Med. Journ.*, 18th April 1868, p. 378.

effects of nitrous oxide were dependent, not upon excess, but upon want of oxygen. It was generally admitted that many of the phenomena which attended the administration of pure nitrous oxide were asphyxial in their type; and it was thought highly probable that the same intimate mechanism which gave birth to the phenomena of asphyxia also gave birth to the phenomena of anæsthesia. There were certain considerations which seemed to support this view. Thus, the unconsciousness was certainly deepest when the asphyxial seizure was at its height, whilst the admixture of air with the anæsthetic gas was believed to interfere with or prevent good anæsthesia. It was soon ascertained, however, that by attention to detail a non-asphyxial form of anæsthesia could be secured by administering air or oxygen with nitrous oxide. Andrews of Chicago was the first to demonstrate this fact (p. 266). Later on Paul Bert devoted much attention to the subject (p. 266), and placed upon a scientific basis the truth at which Andrews had arrived. The French physiologist, however, found that the best results, so far as anæsthesia was concerned, were attainable by increasing the atmospheric pressure at which the nitrous oxide and oxygen were administered (see p. 303). Subsequent experience has shown that whilst such an increase of pressure undoubtedly has certain advantages, it is by no means essential. Even with mixtures containing 20 per cent of oxygen, anæsthesia may be attained at ordinary atmospheric pressures (p. 301). For further remarks on this point the reader is referred to Chapter IX., which deals with the clinical aspects of nitrous oxide.

It became clear then that, whatever the physiological action of nitrous oxide might be, it certainly possessed anæsthetic properties of its own. As regards the asphyxial phenomena which characterised the action of this gas when administered free from air or oxygen, these were to be looked upon as accidental, and dependent upon the crude system of administration. It was difficult or impossible to conceive that the anæsthesia was caused by asphyxia, seeing that anæsthesia still resulted when nitrous oxide was administered with as much free oxygen as was present in atmospheric air. We must be careful, however, of our grounds as we approach

this aspect of the subject. The fact that anæsthesia can be secured by nitrous oxide without producing any *obvious* asphyxial symptoms cannot be held to prove that the anæsthesia of this gas is not dependent upon some alteration in or reduction of the normal oxidation processes taking place within sensory and other nerve-cells. The remarkable influences exerted by increasing and diminishing the percentage of oxygen in nitrous oxide and oxygen mixtures would seem to suggest that there is a very close affinity between the intimate action of nitrous oxide itself upon the central nervous system and the effects of diminishing the normal oxygen supply (see p. 299). It is quite conceivable that the effects of nitrous oxide, ether, and chloroform, when administered with a sufficiency of oxygen to avoid obvious asphyxial (anoxæmic) symptoms, may be the same, and that this action may be of the nature of deoxidation. The initial sensations under nitrous oxide are of an agreeable and stimulant character—almost identical with those of ether and chloroform; and when non-asphyxial and deep nitrous-oxide anæsthesia is established, this anæsthesia is similar in its main features to that produced by other anæsthetics. Were nitrous oxide anæsthesia the result of simple oxygen deprivation we should not expect the initial sensations produced by the inhalation to be of an exhilarating character. Nitrous oxide has, in fact, quite as great a claim as chloroform to be considered a general anæsthetic. It is true that, as the former is gaseous at ordinary temperatures and pressures, it may be administered in its pure state; whilst the latter, being liquid, needs vaporisation. It is also true that the toxicity of nitrous oxide is of a lower order than that of chloroform. Both anæsthetics, however, require dilution with air or oxygen in order that the anæsthesia of each may become satisfactorily established, and this anæsthesia may be readily intensified by reducing the air or oxygen supply.

It has been contended by some observers that the phenomena produced by pure nitrous oxide are one and all special and specific, and that none of them are asphyxial or, more properly speaking, anoxæmic in their nature. This view, however, must now be discarded; for we know that by adding

oxygen to nitrous oxide the stertor, the epileptiform movement, and the cyanosis may be prevented without disturbing the anæsthesia. Animals killed by pure nitrous oxide display post-mortem the usual signs of asphyxia, the right cavities of the heart being full, and the left comparatively empty. George Johnson [1] believed that the great difference in the fulness of the right and left chambers was to be ascribed to contraction of the pulmonary arterioles brought about by the non-oxygenated blood. He maintained that, however asphyxia was induced—whether by nitrous oxide, by nitrogen, or by paralysing respiration by curare—the same effects followed; but, as Dr. P. Black [2] had previously suggested, it is more probable that the distension of the right heart is consequent upon arrest of respiratory movement. Dr. Black appears to have been the first to put forward this explanation of the characteristic post-mortem appearances of asphyxia. As has been pointed out (p. 64), there is ample evidence in administering anæsthetics of the great dependence of the pulse upon the fulness and efficiency of respiration, and whilst it might be going too far to say that the pulmonary stasis of asphyxia is in no way dependent upon the blood condition, it may be affirmed with certainty that the factor of suspended breathing is one of great importance in preventing the passage of blood from the right to the left cardiac cavities. There are, as we might expect, certain differences between the phenomena produced by nitrous oxide, by nitrogen, and by mechanical closure of the trachea; but they one and all lead to fatal asphyxia. As George Johnson urged (p. 457), there are close resemblances between the effects produced by nitrous oxide and those produced by nitrogen. With each of these gases swelling of the tongue, cyanosis, epileptiform spasm, and deep stertor occur. Although both nitrous oxide and nitrogen are respirable to a certain point, they are irrespirable beyond that point. As originally stated by Jolyet and Blanche, nitrous oxide cannot support animal or vegetable life owing to lack of available oxygen. Germinating seeds cease

[1] *Brit. Med. Journ.*, 21st and 28th April 1894. The researches of Bradford, Dean, and others appear to render this theory untenable.
[2] See *Brit. Med. Journ.*, 11th March 1876, p. 316.

to germinate in an atmosphere of the pure gas. In the case of man the average inhalation period is about 56 seconds: at the end of that time fresh oxygen must be admitted to the lungs or permanent asphyxia will result (p. 286). That nitrous oxide and oxygen can be breathed for a long period without materially interfering with respiration or circulation is shown by a remarkable experiment of M. Claude Martin of Lyons, who administered to a dog a mixture of nitrous oxide with 15 per cent of oxygen for three consecutive days (72 hours).[1]

M. Martin employed a chamber of the capacity of 250 litres, and capable of withstanding an internal pressure of 1·5 atmospheres. Dog put in at 5 P.M. 85 parts of nitrous oxide and 15 of oxygen introduced. Pressure progressively raised to 110, 115, and 120 cm. At 6 P.M. dog well anæsthetised. 25 litres of the mixture supplied every hour. Potash solution used to absorb CO_2. After 12 hrs. respiration calm and remained so until end of experiment. After 72 hrs. dog removed. In 15 min. feet commenced to move and eyes opened. 35 min. later made efforts to stand, and trembled as if cold. After 35 min. he moved paws when pricked, and was able to walk and obey commands. He refused milk. Intelligence apparently unimpaired. At 7 A.M. next morning (14 hrs. after experiment) he was in good spirits, and ate well. The total amount of gas consumed was 2500 litres.

The nature of the **blood changes** in nitrous oxide anæsthesia is still *sub judice*. There is no definite evidence that this anæsthetic forms any combination with hæmatin or any substance within the blood, although some such association is regarded by many as highly probable. As already indicated, nitrous oxide is very soluble in blood.[2] According to Davy, it has the power of turning out oxygen or air from water, and it is probable that in addition to its preventing the access of fresh oxygen to venous blood, it actually dislodges more or less completely that oxygen still remaining in it when it reaches the pulmonary capillaries. As regards the gases present in blood during nitrous oxide anæsthesia little is definitely known. Oliver and Garrett[3] in their experiments

[1] See a pamphlet entitled "Sur l'anesthésie prolongée et continue par le mélange de protoxyde d'azote et d'oxygene sous pression (méthode Paul Bert)," by Claude Martin.

[2] See Kemp, *Brit. Med. Journ.*, 20th Nov. 1897, p. 1482.

[3] *Lancet*, 9th Sept. 1893, p. 625.

found that carbonic acid was present in the blood in small quantities as compared with the amounts met with under other anæsthetics; but in a very large quantity relatively to the amount of oxygen. In the case of a rabbit the percentages were CO_2 15·66, O 3·49, N_2O 22·49, and N 11·23 per 100 vols. of blood. Kemp has also found a great reduction in the CO_2 of arterial blood. We can hardly be surprised, however, at the diminution in this gas, seeing that during the inhalation of pure nitrous oxide by the ordinary means, the air supply is cut off. The comparatively large percentage of nitrogen in the above analysis is interesting but difficult of explanation, and it is to be hoped that further researches will be conducted to throw light upon this and other results. Observations are also needed with regard to the blood gases under nitrous oxide and oxygen. Some observers have suggested that by the use of oxygen with nitrous oxide an increased production of CO_2 might lead to a locking-up of this gas within the blood, but it is difficult to see how this could take place provided all expirations escape, as they certainly do in practice, at the expiratory valve. The only condition under which such an accumulation might arise would be that of feeble lung ventilation.

The **blood-pressure** under pure nitrous oxide is markedly raised, as shown by Kemp's tracings.[1] This observer points out that the results which he obtained were clearly parallel to those met with in asphyxia, the excursions of the kymographic tracings being more pronounced than with any other anæsthetic. He found, moreover, that there was no depression of the heart until the respiration had become much affected by pushing the anæsthetic. Buxton[2] has attempted to prove by sphygmographic tracings that there is no rise of tension in the human pulse during nitrous oxide anæsthesia, and he uses this fact—which, however, is a doubtful one—as an argument against any analogy between nitrous oxide anæsthesia and asphyxia. There is little doubt, however, as to the increase in arterial tension. When the usual respiratory embarrassment of deep nitrous oxide anæsthesia takes place, there is necessarily a fall of pressure in the systemic arteries owing to impeded

[1] *Loc. cit.*

[2] *Trans. Odont. Soc.* vol. xviii.

pulmonary circulation; but this late fall of tension is hardly to be regarded as directly due to the nitrous oxide, and it is quickly recovered from when fresh air is admitted to the lungs. Pickering[1] found that after several minutes' action pure nitrous oxide arrested in diastole the embryo heart of the chick; that a mixture of nitrous oxide with 30 per cent of CO_2 rapidly stopped the heart after 30 seconds; but that a mixture of 70 per cent of nitrous oxide and 30 per cent of oxygen stimulated the heart, which still acted after several hours' exposure to the mixture. Kemp finds that the heart beats more strongly under nitrous oxide and air than under nitrogen and air, so that the gas may be said to possess a stimulant effect upon the heart.

As regards the effects of nitrous oxide upon the **kidney**, Kemp[2] states that contraction of the renal vessels takes place, and that urinary secretion rapidly diminishes. He finds that albuminuria is produced, though not to any great extent, in complete narcosis.

When pure nitrous oxide is administered to a **lethal degree**, respiration ceases, and death takes place from asphyxia, the heart continuing to beat, in some cases for several minutes, after the breathing has ceased. The immediate cause of the respiratory arrest is usually, if not always, muscular spasm, and not muscular paralysis (see p. 286).

B. ETHER

Ether occupies a position which, so far as its anæsthetic properties are concerned, is in many respects intermediate between nitrous oxide on the one hand and chloroform on the other. It is more potent than the former; less potent than the latter. Waller's views as to the relative toxicity of ether and chloroform have already been referred to (p. 70). The two main characteristics of ether are: firstly, that it is one of the most energetic stimulants known, not only to the circulatory, but to the respiratory, nervous, and glandular systems of the organism; and secondly, that its vapour is, as compared to that of many other anæsthetics, more irritating to the

[1] *Trans. Odont. Soc.*, Dec. 1893, p. 46. [2] *New York Med. Journ.*, Nov. 1899.

respiratory passages, so that mucus is often freely secreted. Owing to the comparatively feeble toxicity of ether it is usually necessary to administer its vapour in a concentrated form, or to employ the close system of administration (p. 329). By reason of the low boiling-point of the drug it is quickly eliminated from the circulation when the administration is discontinued. As in the case of nitrous oxide, very powerful effects may be secured by limiting the oxygen supply: and the phenomena of etherisation will, as in the case of the phenomena of nitrous oxide, greatly depend upon the extent to which air is withheld during the inhalation.

The Committee of the Royal Medical and Chirurgical Society (1864) found that ether depressed **cardiac action** to a very slight degree, and that in ether toxæmia, respiration usually ceased before the heart, although the pulse might cease before the respiration. They state that in one case they observed the heart cease before respiration. The "Glasgow Committee" came to the conclusion that when frogs, rabbits, and dogs were anæsthetised by ether, and artificial respiration was maintained, the heart continued to beat so long as the experiment lasted. Ringer[1] found that whilst 1 or 2 minims of chloroform arrested the ventricle of the frog's heart, 50 minims of ether merely accelerated and slightly weakened the beats, without interfering with the total quantity of work done. Pickering states[2] that upon the embryonic chick's heart ether produces a powerfully stimulant effect, and that depression only comes about when enormous doses are used.

The Glasgow Committee were unable to satisfy themselves that ether produced any appreciable effect upon **blood-pressure.** Kemp[3] in his experiments upon dogs states that the effect of ether upon general arterial pressure is to raise it from the beginning, even with moderate anæsthesia, and that when the anæsthetic is pushed the pressure rises again slightly. A corresponding fall takes place when the administration is discontinued. In MacWilliam's[4] experiments the blood-pressure usually fell slightly; but there was either no cardiac dilatation or a very

[1] *Practitioner*, vol. xxvi. p. 436.
[2] *Trans. Odont. Soc.*, December 1893, p. 46.
[3] *New York Med. Journ.*, November 1899.
[4] *Brit. Med. Journ.*, 11th October 1890.

slight and transient dilatation, and this was chiefly noticed when ether vapour was given with great suddenness. By administering ether and chloroform alternately to the same animal, MacWilliam found a very marked difference so far as cardiac dilatation was concerned. He affirms that ether depresses the vaso-motor centre, causing arterial dilatation and a general but slight fall of pressure.

The Hyderabad Commission found[1] that strong ether vapour caused holding of the breath and slowing of the heart. The Commission failed, however, to produce true anæsthesia with ether unless air were rigidly excluded during the administration—a failure probably due to the climatic conditions under which the experiments were conducted.

As regards the **blood changes** during and after anæsthesia, these must depend to some extent upon the degree to which respiration is interfered with during the administration. Harley[2] believed that ether was not nearly so powerful as chloroform in diminishing the absorption of oxygen and the elimination of carbonic acid. Von Lerber[3] found that the drug produced practically no effect upon the hæmoglobin of blood, and that in 83 cases in which the urine was spectroscopically examined, there was no increase in urobilin, such as might be expected where the red blood corpuscles disintegrated. On the other hand, Bierfreund finds a hæmoglobin destruction of from 5 to 10 per cent. Oliver and Garrett have come to the conclusion that under the influence of ether the blood and the tissues become deoxidised, but they do not make it clear to what extent destruction of corpuscles is to be held responsible for this effect.

Da Costa and Kaltéyer draw attention to the fact that the preparation of patients by purgation and fasting tends to "inspissate" the blood, and that when profuse perspiration accompanies the inhalation of ether this result must be enhanced. They find also that hæmoglobin is reduced absolutely in amount, and conclude that etherisation produces increased hæmolysis. Anders and Boston,[4] as the result of a

[1] *Report*, p. 29.
[2] *Transactions Roy. Med. and Chir. Society*, 1864, p. 159.
[3] *Year-Book of Treatment*, 1898, p. 166.
[4] *Lancet*, 11th June 1904.

research upon this subject, also find that ether produces increased hæmolysis, which, however, according to their experiments, is followed by rapid regeneration of cells, with an increased number of red corpuscles. A recent research by Dr. F. J. Dawson[1] is in harmony with these conclusions.

The effects of anæsthetics upon the **nitrogenous metabolism** of the body have been estimated so far as ether is concerned. It was found that the chief effect in this respect following upon the administration of ether to a healthy subject was a marked fall in urea excretion upon the day following the inhalation, and a considerable rise on the two subsequent days.[2]

In the course of a research concerning the effects of anæsthetics upon the **kidneys**, Kemp[3] came to the conclusion that ether caused a special contraction of the renal arterioles, and that this contraction led to diminished secretion of urine. He believed that etherisation gave rise to a damaged state of the secreting cells and that albuminuria appeared early in the urine secreted. Oncometric tracings demonstrated a shrinkage of the organ. Buxton and Levy, however, who have repeated the experiments made by Kemp, maintain[4] that this "specific" effect is not constant, and that it occurs chiefly if not wholly in cases in which the ether has been unduly and unnecessarily pushed. In some more recent observations upon etherised dogs Prof. W. H. Thompson finds that the urinary secretion is usually increased during the induction stage; that it is greatly lessened or even arrested during full anæsthesia; and that it is re-established again during the recovery stage. Clinical corroboration of these results has been afforded by a valuable and careful research by Drs. H. Pringle, Maunsell, and S. Pringle.[5] After estimating the amount of urine secreted per half hour by patients prior to etherisation, these observers found that this amount was increased during the period immediately preceding etherisation; that it was sometimes increased and sometimes diminished during the induction stage; that it was invariably diminished during full

[1] *Edin. Med. Journ.*, November 1905, p. 426.

[2] Pechell, *Brit. Med. Journ.*, 20th June 1903, p. 1425.—"The Influence of Ether Administration on Nitrogenous Metabolism."

[3] *New York Med. Journ.*, November 1899.

[4] *Brit. Med. Journ.*, 22nd September 1890, p. 833.

[5] *Ibid.*, 9th September 1905, p. 542.

anæsthesia, the diminution becoming more marked in proportion to the duration of narcosis; and that it again increased during the recovery period. As regards the total nitrogen excreted per half hour, this usually rose and fell with the increase and decrease in urinary secretion. It is suggested that the almost complete inhibition of renal activity which takes place in prolonged etherisation may seriously affect the organism. The observations indicated that the kidney substance recovered its power of secretion of water more rapidly than it regained its power of nitrogenous excretion.

Dr. Hooper[1] of Boston was the first to draw attention to the fact that whilst stimulation of the recurrent laryngeal nerve during light ether anæsthesia produced adduction of the **vocal cords**, stimulation during deep etherisation produced abduction. His results have been corroborated by Semon and Horsley,[2] who maintain that ether produces (through the medium of the circulation) a differential action upon the laryngeal muscles themselves. These observers found, in numerous experiments, that the posterior crico-arytænoid muscles lost their electrical excitability long before the adductors, and whilst they do not offer any explanation of the fact, they point out that a difference in the metabolic processes of the abductor and adductor muscles appears to exist.

According to Dastre, the **temperature** falls somewhat more rapidly with ether than with chloroform.

As regards the **patellar reflex**, Dastre states that it persists, in lower animals, even during complete ether anæsthesia.

C. CHLOROFORM

When **locally applied**, chloroform exerts an irritant or even a vesicant effect. In dilute aqueous solutions it quickly destroys the irritability and contractility of muscles, rendering them "chloroform-rigid," and producing, microscopically, cloudy and

[1] *Transactions Amer. Laryngolog. Association*, vol. vii.
[2] *Brit. Med. Journ.*, 28th August 1886, p. 405, and 4th September 1886, p. 445.—"On an Apparently Peripheral and Differential Action of Ether upon the Laryngeal Muscles."

other structural changes (Bernard [1]). When **subcutaneously injected,** it produces a local anæsthetic effect, but owing to its caustic action upon the tissues it passes but slowly into the general circulation, and by reason of free elimination taking place during its passage through the lungs, deep anæsthesia is not attainable (Dastre). The application of the drug over large cutaneous surfaces has produced general anæsthesia in animals (Brown-Séquard), but this result has been attributed to inhibition of the nervous mechanism involved in the perception of pain. General anæsthesia may be produced by injecting chloroform into veins.

Injections of chloroform into the carotid **arteries** cause, according to Gaskell and Shore, cessation of breathing from paralysis of the respiratory centre, and sudden fall of blood-pressure from paralysis of the vaso-motor centre. That the latter centre was paralysed would seem to be evident from the fact that the cessation of breathing was not followed by an asphyxial rise of pressure; nor did the stimulation of a sensory nerve have any effect in raising pressure.

The effects produced by injecting chloroform into the large **veins** have been much discussed. The Hyderabad Chloroform Commission obtained only the usual phenomena of anæsthesia. The comparatively negative results, however, which were obtained by the Commission were doubtless due, as pointed out by Gaskell, Shore, and Leonard Hill, to the faulty method which they employed, a method which prevented the chloroform mixing with the venous blood and passing into the heart cavities. Gaskell, Shore, Hare, Thornton, and Leonard Hill all agree as to the depressing effect which chloroform produces upon the heart when the drug is thus introduced into the circulation. The last-named physiologist finds that if 1·5 min. of chloroform be injected into the jugular vein and washed in with saline fluid, a brief stimulant effect is produced which is followed by a diminution in the output of the systole, and slight dilatation; whilst 5 mins. have the effect of instantly producing profound dilatation and feebleness of action. The tracing of Fig. 1. clearly shows these effects.

The results of the **ingestion** of considerable quantities of

[1] *Leçons sur les Anesthésiques et sur l'Asphyxie.*

chloroform are not without interest in this connection, and are well illustrated by a case[1] reported by Dr. John Hayward. Two ounces were swallowed, and death occurred from syncope during the act of retching. The author has also been furnished with notes of a case in which a melancholic patient attempted to commit suicide by swallowing chloroform. For a space of 15

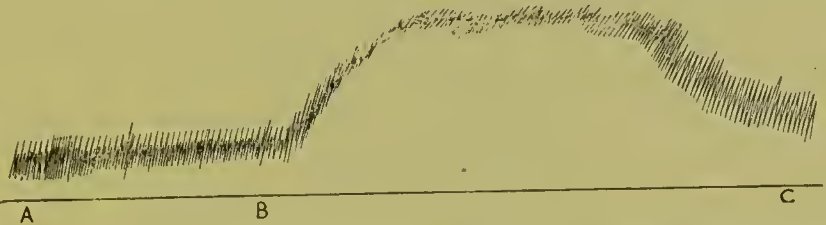


FIG. 1.[2]—Heart enclosed in tennis ball connected with piston recorder. Record of diastolic and systolic volume. A, 1·5 min. of chloroform injected into jugular vein. B, 5 mins. injected. Great diastolic distention shown by rise of base line and small systolic strokes. Paralytic distention of heart. C, Heart recovered from distention. In other experiments 5 mins. proved fatal.

minutes there was no attempt at breathing, nor could any pulse be detected. Life was saved by vigorous and protracted artificial respiration. The case is interesting by reason of the fact that complete unconsciousness persisted for 18 hours.

We have now to consider the physiological effects produced by chloroform when introduced in a vaporised state into the circulation through the **respiratory passages** of the organism.

Snow was the first observer to recognise the importance of **vapour dilution**, and to administer chloroform by **quantitative** or **dosimetric methods**. (See remarks on the dosage of anæsthetics, p. 49). He carefully conducted a series of experiments upon animals with the object of ascertaining the **percentages** of chloroform vapour needed to produce the various "degrees of narcotism" (p. 83), which he described; and he also roughly calculated the actual quantities of chloroform which were present in the blood at various stages in the administration. He arrived at the conclusion that one grain of chloroform to every 100 cubic inches of air sufficed to induce his "second degree of narcotism," the fraction $\frac{1}{56}$ expressing the degree of saturation of the air from which the vapour was immediately absorbed into the blood, and consequently also the degree of saturation of the blood itself.[3] He further found that two grains of chloroform to every 100 cubic inches of inspired air caused a state of very

[1] Dr. Leonard Hill's tracing. See *Brit. Med. Journ.*, 20th Nov. 1897, p. 1497.
[2] *Brit. Med. Journ.*, 11th Oct. 1902.
[3] More recent researches show that the association between chloroform and blood is not merely one of simple solution.

complete insensibility, corresponding with his "fourth degree of narcotism"; and the fraction $\frac{1}{28}$ expressed the extent of saturation of the blood in this degree. As regards quantities of chloroform exceeding two grains to 100 cubic inches of air, these had a tendency to embarrass and arrest the function of respiration, provided that the inhalation were continued; and he calculated that three grains of chloroform to every 100 cubic inches of air was very nearly the quantity which had the power of arresting the breathing when the temperature of the body was 100°, the fraction $\frac{1}{18}$ or $\frac{1}{19}$ representing the blood saturation in this toxic state. Snow also calculated that for his second degree of narcotism it was necessary that the blood of an average adult patient should contain about 12 minims; for the third degree, 18 minims; for the fourth degree, 24 minims; and for the arrest of respiration, about 36 minims.

The Royal Medical and Chirurgical Committee found that with atmospheres containing from 2 to 4 per cent of chloroform vapour there was little or no risk to life; but that in some cases it was necessary to employ an atmosphere containing as much as 5 per cent of vapour. Stronger atmospheres induced alarming symptoms.

Paul Bert's results were similar to those obtained by Snow. With 4 grammes of chloroform to 100 litres of air insensibility was not produced, but the animal died at the end of 9 or 10 hours with a low temperature. With 6 grammes to 100 litres a diminution of sensibility was noted, and the animal died at the end of 6 or 7 hours. With 8 grammes to 100 litres insensibility was slowly produced, and death took place in 4 hours. With 10 grammes to 100 litres[1] anæsthesia was obtained in a few minutes, and death took place in 2 or 3 hours. With 12 grammes to 100 litres the animal died in rather less than 2 hours. With 15 grammes to 100 litres death occurred in 40 minutes; with 20 grammes to 100 litres, in 30 minutes; with 30 grammes to 100 litres, in 3 minutes. As Dastre points out, it is interesting that weak chloroform atmospheres affected nutrition without destroying sensibility.

Of the various ingenious **instruments** by means of which the physiologist is enabled to administer definite percentage mixtures of chloroform vapour and air, those of Dubois, of Waller, and of Collingwood deserve brief notice.

In **Dubois' apparatus**,[2] air is expressed from a small cylindrical gasometer containing four litres, by means of a piston working inside the cylinder. As the piston rises, four litres of air are expelled above the piston and pass through a tube into a face-piece. At the same time air rushes into the cylinder below the piston. As the piston descends, the action is reversed. The air below the piston now rushes out into the face-piece, and there is an inrush of air into the cylinder above the piston.

[1] This mixture is roughly equivalent to a 2 per cent mixture of chloroform vapour and air.

[2] I am indebted to Dr. Paul Chapman of Hereford for this description.

When the apparatus is in use, the inrush of air always takes place closely over the surface of a few drops of liquid chloroform thinly spread out at the bottom of a vessel. By this means the few drops are completely vaporised. It is necessary that the few drops of chloroform

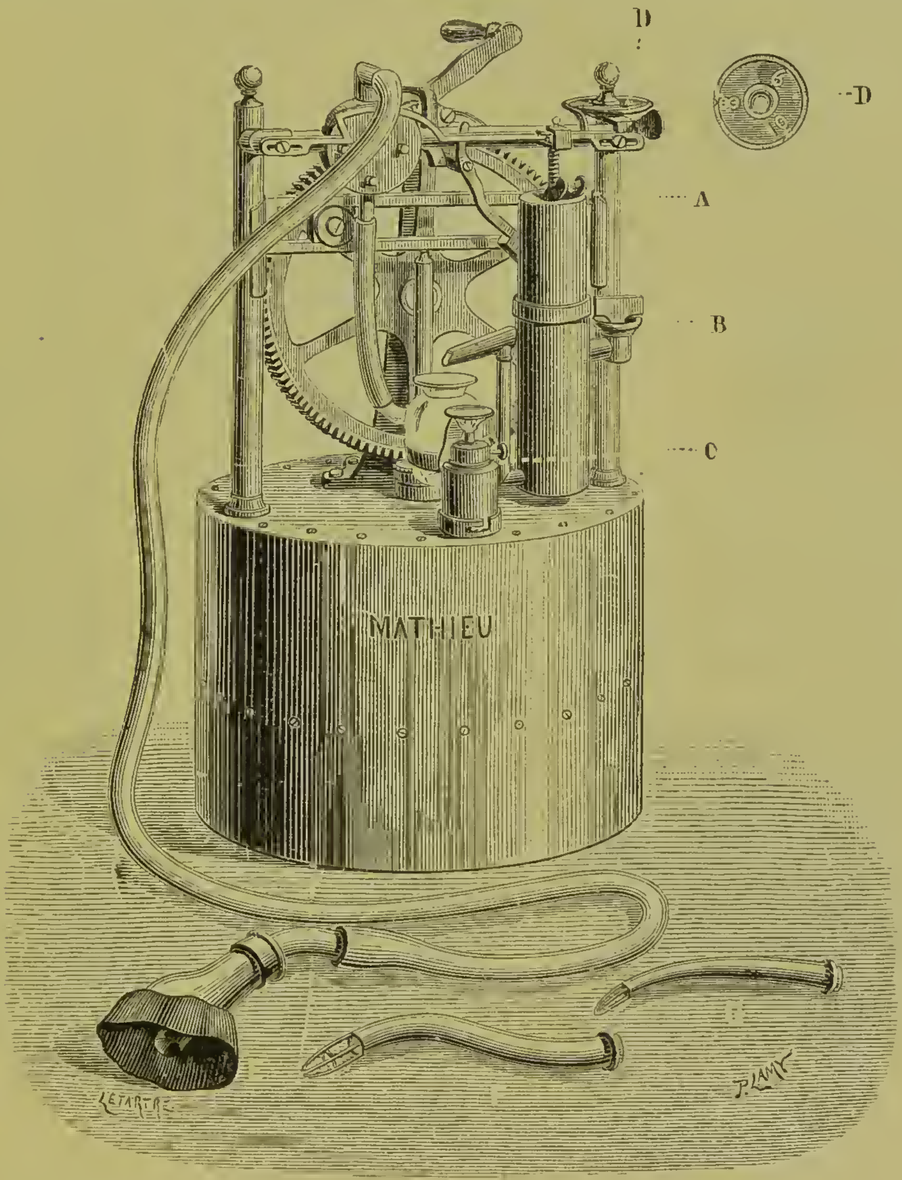


FIG. 2.—Dubois' Chloroform Apparatus. A, plunger; B, chloroform vase; C, spirit lamp; D, cam; E, face-piece; F, G, end pieces which may be substituted for face-pieces.

should be supplied in constant quantity, and that they should be instilled into the vessel just before each upward and downward movement of the piston previous to the inrush of air. Therefore use is made of the momentary dead-points occurring at the reversal of the upward or downward movement of the piston. The piston is moved by a wheel moving always in one direction, the reversal of the movement of the piston being automatic.

Projecting laterally from the circumference of the wheel are two little nuts which alternately catch (at the moment of the reversal of the movement of the piston) on the arm of a crank which moves a horizontal lever. At each thrust of the lever in a horizontal direction, movement is imparted to a vertical screw, which conveys a slight downward movement to a plunger attached to it. The plunger dips into a small cylindrical vessel (clamped beneath it, but easily detachable) containing when full

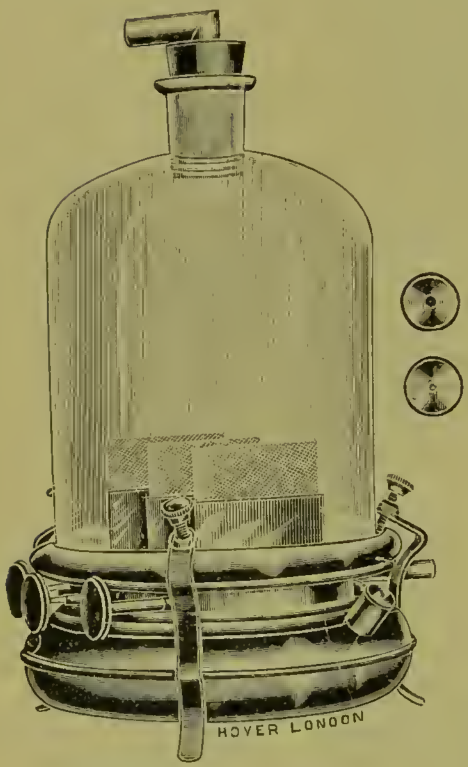


FIG. 3.—Waller's Wick Vaporiser.

FIG. 3A.—Waller's Wick Vaporiser in use.

some four ounces of liquid chloroform. At each descent of the plunger a uniformly regulated number of drops of $CHCl_3$ run out of the vessel, through a lip projecting from the upper part of it, into the before-mentioned small vessel, through which the inrush of air passes, and where it is wholly vaporised. By means of a "cam" the horizontal movements of the lever can be made more or less excursive, thereby taking up fewer or more cogs connected with the vertical screw carrying the plunger. By this means it is easy to obtain, within minute limits, a faithful percentage of 1·2 per cent, 1·6 per cent, or 2 per cent of chloroform vapour.

Waller's wick vaporiser [1] depends for its action upon the exposure of chloroform-saturated wicks of known area to an air current constantly passing through the vaporiser. A glass reservoir is employed (Fig. 3) containing a 3-wick lamp with a breadth of wick 66 mm., so that a length of 75 mm. exposes an area of evaporation of 50 cm. He finds that at ordinary room temperatures this area gives off rather more than 1 per cent of vapour to a continuous air-current of 8 to 12 litres per minute pumped through the vaporiser by a foot bellows, and that a second and third wick raise the percentages to about 2 per cent and to nearly 3 per cent. The anæsthesia of small animals—up to ten or twelve kilos—is induced in a 15 or 30 litre bell jar supplied with chloroform-laden air from the vaporiser. Anæsthesia is subsequently maintained through a tracheal tube connected directly with the vaporiser.

Collingwood's apparatus for the delivery of chloroform vapour of

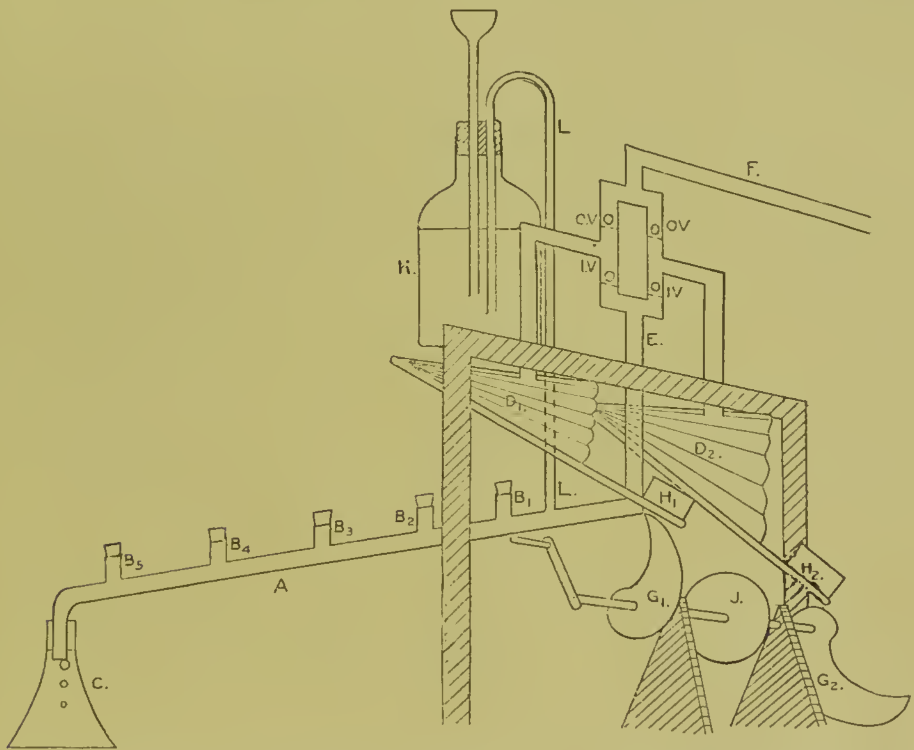


FIG. 4.—Collingwood's Chloroform Apparatus. A, inclined tube through which chloroform runs; B_1, B_2, B_3, B_4, B_5, inlets for air; C, bottle into which excess of chloroform drops; D_1, D_2, bellows; E, connecting tube between valves and inclined tubes; F, delivery tube; G_1, G_2, cams on shaft; H_1, H_2, weights on bellows; J, grooved wheel to connect with motor; K, chloroform flask; L, syphon; OV, OV, outlet valves; IV, IV, inlet valves.

known dilution [2] attains its end by drawing air up an inclined tube, down which a fine stream of chloroform is constantly running. By opening one or more inlets in this tube the proportion of air to chloroform

[1] *Proc. Phys. Soc.*, 19th Aug. 1904.
[2] This has been recently described before the Roy. Med. and Chir. Soc.

vapour may be regulated, the air passing over a longer or shorter stream of chloroform, as the case may be. Air gains access to the tube by the alternate suction action of two bellows worked either by the hand or by a motor. Collingwood has obtained with this apparatus very constant results in the percentage composition of the chloroform atmospheres delivered.

All the above ingenious instruments deliver chloroform atmospheres of known percentages by what has been termed the "plenum" system, the animal receiving the diluted vapour at a slightly positive pressure, *i.e.* without any suction action on its part. This is a matter of no small importance, the plenum system being free from certain definite objections which surround the suction action system (p. 113). Moreover, careful estimations have proved that all these instruments are reliable as regards their percentages.

It is very important that the rôle played by the **percentage** of chloroform in chloroform atmospheres should be clearly understood. Were all chloroform accidents attributable, as many believe them to be, to vapour concentration it would be impossible to over-estimate the value of this factor. As many of the dangers, however, during chloroformisation may arise during the inhalation of the most perfectly adjusted mixture, we must not fall into the error of regarding chloroform concentration as the invariable cause of difficulties.

A very interesting physiological experiment is recorded in connection with the work of the present Special Chloroform Committee of the British Medical Association (*Brit. Med. Journ.*, 14th July 1906, p. 82). A small cat, rather thin, but otherwise healthy, was anæsthetised with an exceedingly weak (1·06) chloroform mixture. It is to be noted that the anæsthetic was administered *by means of a mask and not through a tracheal cannula.* The percentage mixture used in this experiment was weaker than that employed in any of the other experiments of this particular research, in all of which no other fatality occurred. "The depth of the respiration decreased almost at once, and at the end of the fourth minute respiration ceased. The heart was still beating, though feebly, and soon stopped. Attempts to recover the animal by massage of the heart and by artificial respiration were unavailing." From the point of view of those who consider that low vapour percentages necessarily mean safety, this death is, naturally enough, inexplicable; but considered in the light of the principles laid down in these pages, it is readily intelligible. The differences between face-piece administrations and tracheal cannula administrations are fully considered on p. 41. It is in the highest

degree probable that in this particular physiological experiment, as in a large proportion of fatalities in practice, some obstructive element was present.

The author has recently had reported to him an interesting clinical illustration of the point under consideration. The patient was an elderly man of spare build, with a beard. He had a somewhat receding lower jaw and slight nasal inadequacy. There were no upper teeth and the lower therefore came in contact with the upper gum. The patient's general condition was good; his heart sounds were distinct and normal; he had no cough. The operation was for mastoid disease. Chloroform was administered by a well-known anæsthetist, and the Vernon-Harcourt inhaler was employed. It was necessary to envelop the face-piece with a towel, in order to exclude the surrounding air. A bystander observed that the patient was not obtaining a sufficient supply of air. Whilst the operation was in progress both pulse and respiration ceased, the eyes appeared glazed, and it was thought that the patient was dead. The tongue was drawn out and artificial respiration performed, and fortunately the patient recovered. The author anæsthetised this patient about ten days later, employing the C.E. chloroform sequence, and administering the latter anæsthetic by means of a Skinner's mask. Owing to the physical state of the upper air passages, there was some tendency towards obstructed breathing throughout; but this was easily prevented by keeping the finger within the mouth, separating the tongue from the palate and hooking the lower jaw forwards. Circulation was well maintained throughout the operation. It was quite clear that in this particular case a tightly fitting face-piece could not have been applied without embarrassing breathing, the slightest pressure at once limiting the ingress of air. It is in the highest degree probable that the combination of a Vernon-Harcourt face-piece and the suction-action of that inhaler had brought about, in this particular patient, an intercurrent asphyxial state which nearly proved fatal.

Although intercurrent asphyxia, surgical shock, and other conditions are often responsible for the occurrence of dangerous symptoms under chloroform, the question of vapour concentration is doubtless an important one. There are in fact percentages which are *in themselves* safe, whilst there are others only slightly higher which are *in themselves* dangerous. We may therefore speak of **certain limits** which are safe *so far as the avoidance of toxic symptoms is concerned.* By restricting our percentages, we eliminate at least one important element of risk. There is still some difference of opinion, however, as to what should be regarded as the maximum limit; but most observers agree that mixtures containing more than 3 per cent of vapour should be avoided. Waller places

the maximum as low as 2 per cent. Embley, who regards vagus inhibition from vapour concentration as the chief risk in chloroform administration, considers that a vapour of even 2 per cent is dangerous and places the limit at 1 to 1·5 per cent. As regards the most appropriate percentage for anæsthetisation, this can hardly be stated in a hard and fast rule. Different lower animals require different percentages, to produce a given effect; the same animal may require different percentages according to the nature and duration of the surgical stimulus; and variations in percentage may be needed as the anæsthetisation proceeds. Sherrington has shown that cats' hearts differ in their susceptibility to definite doses of chloroform. When different animals are simultaneously subjected to the same chloroform atmosphere, they become anæsthetised, not simultaneously, but successively. The state of anæsthesia produced by the physiologist is not necessarily appropriate for a given surgical procedure. When using his apparatus already described, and employing cats and dogs as subjects, Collingwood found that 1·0 per cent of chloroform vapour sufficed to keep the corneal reflex in abeyance after an anæsthetisation of half an hour, ·8 per cent after one hour, ·5 per cent after four hours, and ·4 per cent after five hours.

The **absorption** of chloroform by the pulmonary circulation during a given period has lately occupied the attention of physiologists.

Waller [1] has made some interesting calculations in this direction, the excess of income over output representing the quantity of chloroform retained in the body during a given period. In the case of a cat the total amount of chloroformed air inspired was 9 litres in 7 minutes 40 seconds, the percentage of chloroform vapour in this mixture being 2·7. The total volume of chloroform vapour inspired was therefore 243 c.c. or rather more than 1 gm. of fluid chloroform. The expired air showed a percentage of 2·1 (after correcting for CO_2) or 189 c.c. of chloroform vapour were rejected in the 9 litres of expired air, so that we have

Chloroform inspired 243 c.c.
Chloroform rejected 189 c.c.
Chloroform retained 54 c.c. = ·27 gm.

The same cat was subsequently made to breathe a much higher percentage, the composition of the inspired and expired currents being calculated, as

[1] *Lancet*, 28th Nov. 1903, p. 1484.

before, by Waller's densimetric method (p. 27). The inspired atmosphere contained 14·2 per cent of chloroform; the expired 7·9 per cent (corrected for CO_2). The total volume of air breathed was two litres in three minutes, when respiration ceased. The following figures were obtained:—

Chloroform inspired 284 c.c.
,, rejected 158 c.c.
,, retained 126 c.c. = ·63 gm.

In the former experiment the animal was fully anæsthetised by chloroform absorbed at the rate of 35 mgm. per minute; in the latter the same animal was killed by chloroform absorbed at the rate of 210 mgm. per minute.

In the course of a preliminary investigation upon the rate of absorption of chloroform during the induction of anæsthesia,[1] Brodie and Widdows found that the percentage of chloroform in the expired air was least in the first two minutes, the minimum being nearly always reached in the second minute. Subsequently the percentage rose, but it remained below that of the mixture inhaled even in the tenth minute. Generally speaking the amount of chloroform absorbed increased with the concentration of the chloroform in the anæsthetic mixture, but it was by no means in proportion to that concentration.

Vernon Harcourt,[2] in the course of some experiments concerning the proportion of chloroform retained by patients during and after the use of his inhaler, found that about one-third of the total amount of chloroform used was retained at the conclusion of anæsthetisation.

As regards the **respiratory phenomena** of chloroform anæsthesia, little remains to be added to what has already been said in discussing respiration under anæsthetics in general (p. 57) and the differences between simple and complex chloroform anæsthesia (p. 41). The remarks already made in these preceding pages apply, indeed, with special force to chloroform. Many years ago Claude Bernard and the Committee of the Royal Medical and Chirurgical Society pointed out that if chloroform were given in a concentrated form, intercurrent asphyxial complications were at once introduced, and free breathing was more or less completely suspended from reflex closure of the larynx. This reflex suspension of breathing, however, does not appear to be dangerous in the case of lower animals, even though associated, as it often is, with temporary cardiac inhibition. The principal risk in a concentrated vapour is that of simple toxæmia.

When chloroform narcosis is well established, the

[1] *Brit. Med. Journ.*, 14th July 1906, p. 79.
[2] *Ibid.*, 14th July 1906, p. 83.

breathing is generally quiet and inclined to be shallow; but much will depend upon the activity of the cerebral circulation. Paul Bert,[1] in his experiments upon dogs, found that costal breathing became gradually less marked, and that eventually most of the respiratory work was carried on by the diaphragm. If diaphragmatic breathing were paralysed by section of the phrenics, costal breathing began. As regards the expansive force of respiration, this is diminished in proportion to the degree of narcosis. Thus, Dastre found, in the case of a dog of 12 kilos. 850 grammes, whose respiration became arrested by a weight of 75 kilos. when no anæsthetic was administered, that respiratory arrest during anæsthesia occurred with a weight of 58, 55, or 25 kilos., according to the duration of the insensibility. The same author states that the experiments of Langlois and Richet led these observers to the conclusion that, during anæsthesia, expiration was considerably more depressed than inspiration. The inspiratory efforts of an anæsthetised dog were not much modified by anæsthesia; but there was a considerable reduction in the expiratory force.

As regards the immediate causation of respiratory failure in chloroform toxæmia, there is good evidence that, in addition to the factor of the anæsthetic itself acting upon the nervous mechanism of breathing, and bringing about respiratory paralysis, there is often another, and perhaps a more important factor present, viz. low arterial tension. This is well seen in Fig. 5. As already pointed out, low arterial pressure may depend upon numerous causes; but whatever these causes may be, the effect upon respiration will be the same, provided the fall be sufficiently acute. The dependence of respiration upon circulation was pointed out many years ago by the Glasgow Committee; and more recently Gaskell, Shore, Hill, and Embley have brought forward corroborative evidence in the same direction. The point has such an important bearing in practice that a second tracing (Fig. 6) is worthy of study. Hill maintains that the tracings of the Hyderabad Chloroform Commission also conclusively prove that circulatory failure is a common cause of respiratory arrest.

[1] Dastre, *op. cit.*

Salivation is generally somewhat increased during the early stages of chloroformisation, and diminished during deep anæs-

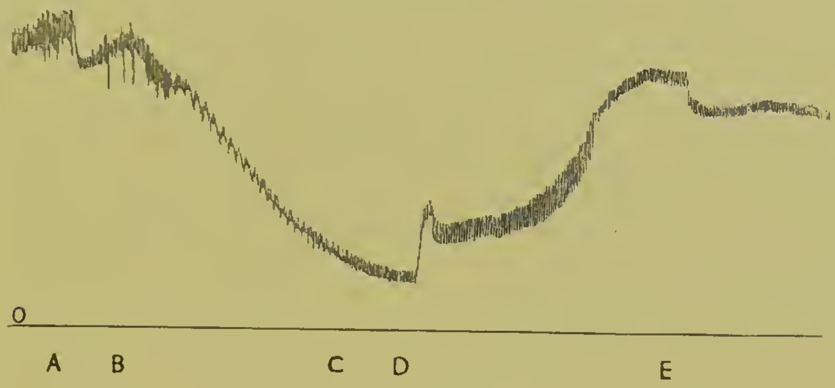


FIG. 5.—(Published in the *Journal of Physiology* in Paper 1—"On the Influence of Gravity on the Circulation.") Cannula in carotid placed in axis of rotation. Dog. Morphia. At the bottom of the fall produced by chloroform the respiratory waves disappear. On turning the animal feet-up the blood-pressure rises and the respiratory waves immediately reappear on the trace. This shows that paralysis of the respiratory centre is partly due to fall of arterial pressure. A, Feet-down: vertical posture. B, Chloroform pushed. C. Withdrawn. D, Feet-up posture. E, Horizontal.

thesia. According to Dastre, the chorda tympani retains its

FIG. 6.—(Embley, *Brit. Med. Journ.* 19th April 1902, p. 957). Showing "Relation of respiration to circulation. Respiration the upper, and blood-pressure the lower tracing. Dog, weight 33lb. Morphine, 0·5 gram. Chloroform, 6 per cent vapour in air taken in respiration at 'started,' and continued till the respiration ceased. Respiration ceased when the blood-pressure was equal to 16 mm. mercury-pressure. Vagi were cut and the blood-pressure rose. Respiration recommenced when the blood-pressure had reached 92 mm. mercury-pressure."

excito-secretory action throughout, whilst the reflex action of

the lingual nerve on the submaxillary gland is lost soon after the corneal reflex disappears.

As regards the **respiratory exchanges** under chloroform, Arloing[1] found that less oxygen was absorbed and less carbonic acid exhaled than under normal circumstances, but that the diminution was most marked in the case of the latter gas. Paul Bert's experiments led him to the same conclusion. Thus[2] in one experiment he found that before anæsthesia the absorption of oxygen was 9·9 litres per hour; and the production of CO_2 9·55 litres. Five minutes after the cornea had become insensitive the results were: Oxygen 6·57; CO_2 5·26. After 45 minutes' anæsthesia the figures were: Oxygen 4·42; CO_2 3·39. And after 90 minutes' anæsthesia: Oxygen 3·69, and CO_2 2·39. It will be seen from these figures that there was a progressively greater diminution in the CO_2 excreted than in the oxygen absorbed—in other words, a lowering of the "respiratory quotient"—the diminution in the oxygen absorbed and in the CO_2 evolved pointing to diminished tissue changes. As we have already seen (p. 62), Rumpf arrived at results similar to those of Paul Bert. The Glasgow Committee, however, came to the conclusion that an *increased* amount of CO_2 was exhaled during chloroform anæsthesia.

With regard to the **blood changes** during chloroformisation, Harley[3] believed that chloroform diminished the power of the constituents of the blood to unite with oxygen and to give off carbonic acid, and Oliver and Garrett[4] have endorsed his views. He described various degrees of disintegration of the red blood cells as referable to the action of chloroform, and corroborative evidence in the same direction has been advanced by Ostertag, M'Kendrick, Sansom, Wittich, and Böttcher.[5] McKendrick[6] Coats, and Newman, studying the effects of the inhalation of chloroform on the pulmonary circulation of the frog, also observed disintegration of corpuscles. On the other hand it is

[1] Dastre, *op. cit.* [2] Dastre, *op. cit.*

[3] *Transactions Roy. Med. Chir. Soc.*, 1864, p. 159.

[4] *Lancet*, 9th Sept. 1893.

[5] I am indebted for this and other statements on this subject to Dr. Guthrie's excellent article in the *Clin. Journ.*, 24th March 1897.

[6] *Brit. Med. Journ.*, Dec. 1880.

contended by some observers[1] that chloroform is only feebly hæmolytic and has but little action in destroying the red blood corpuscles and practically no action in reducing hæmoglobin. Schmiedelberg, Pohl,[2] and Franz[3] believe that chloroform, when circulating in the blood, is in some way associated with its fatty constituents and especially with lecithin and cholesterin. Pohl found that the blood of a dog under chloroform contained from ·01 to ·06 per cent of chloroform,[4] the average amount being ·035 per cent; and that the red corpuscles contained about two and a half times more than the serum. Tunnicliffe and Rosenheim[5] showed that the effect produced by relatively strong solutions of chloroform upon the isolated heart was somewhat delayed by the presence of lecithin. Sherrington and Sowton[6] find that chloroform in blood is less toxic to the heart than chloroform in saline solution. Quite recently Moore and Roaf[7] have conducted an elaborate research on the properties of solutions of chloroform in water, saline, serum, and hæmoglobin, and conclude that chloroform forms an unstable chemical compound or physical aggregation with blood proteids, and that it is thus carried by the blood. They find that chloroform has a distinctly higher solubility in serum or hæmoglobin solutions than in saline or water, and that the oxygen-carrying power of hæmoglobin is not interfered with in the presence of chloroform. In an independent research Waller[8] has come to similar conclusions. When whipped bullocks' blood was treated with chloroform and an attempt was made to remove the latter, the deficit was found to be 85 per cent.

Little is definitely known concerning the **gases of the blood** in chloroform anæsthesia. Bert, in his experiments with his "Melanges titrés," found that as regards the blood, as the administration proceeded, a progressive diminution in the quantity of oxygen and an increase in that of carbonic acid

[1] See a paper by Dr. F. J. Dawson in the *Edin. Med. Journ.*, 1905, p. 426.
[2] *Archiv fur Exp. Path. und Pharm.*, 1891, p. 255.
[3] *Dissert. Würzburg*, 1895.
[4] Taylor's *Jurisprudence*, 4th edit., p. 425.
[5] *Journ. Phys.*, vol. xxix., p. 15 of Proc.
[6] Brit. Med. Assoc. Chloroform Committee.
[7] *Proc. Roy. Soc.*, vol. lxxiii., 1904, p. 382.
[8] *Ibid.*, vol. lxxiv.

took place. In the case of his 12 : 100 mixture (*vide supra*) the following were the figures :—

Before Anæsthesia.		After 30 minutes' Anæsthesia.	
O	22	O	16·8
CO_2	31·2	CO_2	41·2

An hour later he found :—

O	14
CO_2	44

Similar results have been obtained by De St. Martin.[1]

This observer found the blood gases of a dog, before chloroform was administered, to be as follows :—

O	15·20
CO_2	40·85
N	2·45
	58·50

The observation was made at 9.50 A.M. Five minutes later the inhalation of chloroform was begun. At 10.7 A.M. the animal was asleep, and at 10.10 A.M. the blood contained :—

O	15·05
CO_2	36·40
N	2·85
	54·30

The administration was continued, and half an hour later a further analysis gave :—

O	12·88
CO_2	50·62
N	3·05
	66·55

As regards venous blood, Paul Bert found that the oxygen showed diminution, but the CO_2 remained about stationary. The researches of Oliver and Garrett[2] give the following figures :—

[1] *Recherches experimentales sur la Respiration*, p. 189. Quoted by Oliver and Garrett, *Lancet*, 9th Sept. 1893.

[2] *Loc. cit.*

Dog. Arterial Blood. Chloroform Anæsthesia.

CO_2	37·21
O	17·09
N	8·03
$CHCl_3$	0·92

Rabbit. Arterial Blood. Chloroform Anæsthesia.

	(A)	(B)	(L)
CO_2	6·46	19·33	24·85
O	20·96	16·86	13·14
N	54·72	38·33	13·7
$CHCl_3$		4·55	2·59

Rabbit. Chloroform and Oxygen.

	(M)	(N)	(O)	(P)	(U)
CO_2	45·18	58·43	37·26	26·38	35·96
O	21·02	16·06	22·95	19·03	16·83
N	8·96	11·56	11·65	8·92	6·62
$CHCl_3$	1·18	1·20	0·62	1·5	trace

The most curious feature in the above figures is the large proportion of nitrogen. Further research is necessary before these results can be discussed.

The direct action of chloroform upon **blood-vessels** is of interest in relation to the causes of the fall of blood-pressure during chloroform anæsthesia. The view now generally accepted is that the whole cardio-vascular system tends to dilate as the result of the direct effects of the drug, although some observers maintain that, in certain vessels at all events, a constrictive action is produced. In conjunction with Martin, Embley has studied the action of anæsthetic quantities of chloroform upon the blood-vessels of the bowel and kidney.[1] These observers find a marked dilatation due to the direct effects of chloroform upon the neuro-muscular mechanism of the blood-vessels of these organs, and conclude that a considerable part of the fall in blood-pressure constantly associated with the administration of chloroform may be thus explained. Schäfer and Scharlieb [2] maintain, however, that chloroform has

[1] *Trans. Phys. Soc.*, vol. xxxii., No. 2, 28th Feb. 1905, p. 147.
[2] *Trans. Roy. Soc. of Edin.*, vol. xli., Part 2, No. 12.

a direct constrictive action upon the muscular elements of most peripheral blood-vessels, although they admit that in the case of the renal vessels dilatation occurs. They regard the fall of blood-pressure which takes place under chloroform as due principally to cardiac weakening, and look upon the constrictive action of the blood-vessels as counteracting, to some extent, this fall of pressure.

We have next to consider the question: What is the **direct action of chloroform upon the heart?** Snow's observations led him to the conclusion that *primary* cardiac paralysis only took place with high percentages of vapour, and that, provided precautions were taken to avoid such concentration, the heart only failed secondarily to the breathing. In the case of cats, chloroform atmospheres of 3 per cent to 6 per cent caused stoppage of breathing before arrest of the heart—an interval of two or three minutes separating the cessation of respiratory and cardiac action in many cases. But with atmospheres of 8 per cent to 10 per cent "the action of the heart was always seriously affected and rendered extremely feeble, if it did not actually cease, at the time the breathing was arrested." The experiments of the Committee of the Royal Medical and Chirurgical Society also pointed in the same direction. The Committee found that the strongest doses of chloroform destroyed animal life by arresting the action of the heart, and that moderate doses considerably weakened cardiac action before death ensued, although respiration generally ceased before the heart's action completely failed. The strongest doses of chloroform caused the pulse and respiration to cease nearly simultaneously (in from 1′ 20″ to 1′ 45″), whilst the heart's action continued for a short time subsequently (from 3′ 10″ to 5′ 30″). When, however, equally strong atmospheres were administered through an opening below the glottis, death was much more rapid, "and the heart, as a rule, ceased to beat several seconds before the final arrest of the respiratory movements." With moderately strong and weak vapours little or no difference was observed, whether the chloroform entered above or below the glottis. The Committee found that a strong chloroform vapour did not cause a more permanent stoppage of the heart's action than a milder vapour. Some

years later (1879-80) the Glasgow Committee arrived at very similar conclusions. Not only did they find that in the dog, rabbit, and frog, cardiac action soon ceased under chloroform—far sooner than under ether[1]—but they came to the conclusion that chloroform sometimes exerted an unexpected and capricious action on the heart, causing a rapid fall of pressure—a conclusion which was subsequently challenged and criticised by the Hyderabad Commission, who regarded the tracing upon which the Glasgow Committee had based their views as indicating an asphyxial element in the administration. Ringer showed[2] that, so far as the frog's heart was concerned, chloroform undoubtedly produced a powerfully depressant effect upon the muscular tissue itself. On the other hand, the Hyderabad Commission attempted to prove by a large number of observations that, during the administration of chloroform, the heart was never primarily affected—in other words, that its action was maintained till respiration had ceased. As we have already pointed out, however (p. 17), these observations have not been accepted by the physiological world. Some years ago MacWilliam clearly showed that under chloroform a varying degree of dilatation of the heart's cavities took place, the dilatation commonly commencing when the corneal reflex disappeared. All chambers shared in the dilatation, and when the anæsthetic was lessened the dilatation usually ceased. In some cases the dilatation was rather sudden, and it was as a rule independent of rate. When the dilatation was extreme the heart failed, although rhythmic movements persisted for a while. MacWilliam further found that the cardiac dilatation was not due to fall of pressure, nor was it dependent upon increased pulmonary resistance from vascular contraction. It was, in fact, due to the effect of chloroform on the heart itself. He observed, in some cases, periodic cardiac dilatation *after* chloroform, and found that ether dispelled this. Dilatation did not usually come on after blood-pressure had fallen. In some cases MacWilliam observed a state of "delirium cordis"—the ventricle being thrown into a condition of inco-ordinated fibrillar contractions. Gaskell's and Shore's

[1] *Brit. Med. Journ.*, vol. i., 1879, p. 1.
[2] *Practitioner*, vol. xxvi. p. 436.

experiments[1] also led them to the conclusion that chloroform exerted a direct paralysing influence upon the heart and blood-vessels; and they pointed out that the so-called proof in the Hyderabad tracings, that chloroform did not depress the heart, was in every case an instance of a slight increase in the size of the pulse-excursions due to a slowing of the heart's action. Wood and Hare[2] also showed that chloroform had a direct effect upon the heart itself. Experimenting with the embryonic heart of the chick—*i.e.* with a heart not yet supplied with any nervous mechanism—Pickering[3] found that ·5 c.c. of a chloroform solution containing ·00003 c.c. of pure chloroform, when injected under the blastoderm of the embryo, rapidly reduced its cardiac rhythm and produced an exaggerated diastole. After the injection of ·00004 c.c. the heart stopped in a dilated condition. He found a mixture of CO_2 and chloroform to be far more toxic to the embryonic heart than a mixture of chloroform and air. The final proof of the error of the Hyderabad doctrine was, however, brought forward by Leonard Hill, who showed that the methods employed by the Commission for registering the efficiency of cardiac contraction were faulty. Hill corroborated MacWilliam's original observations as to chloroform producing paralytic dilatation of the heart. He found that it acted directly, like amyl nitrite, on the musculature of the whole vascular system. He very properly laid stress upon a point which is fully discussed in the clinical part of this work, viz. that the real question is—When does the heart *cease to expel its blood?* not—When does it cease to make *efforts at contraction?* If a dog be killed by a concentrated chloroform vapour, respiration will usually continue longer than the femoral pulse; and if the chest be opened, the heart will be found much dilated and exhibiting waves of contraction although unable to empty its cavities. These waves, in fact, are ineffectual in maintaining a circulation—the heart having failed to act as a *circulatory organ*. Hill and Barnard also made some experiments, the results of which coincided with those previously obtained by Gaskell and

[1] *Brit. Med. Journ.*, 28th Jan. 1893.
[2] *Medical News* (Phila.), 22nd Feb. 1890.
[3] *Trans. Odont. Soc.*, vol. xxvi. No. 2, N.S., Dec. 1893, p. 42.

Shore, and they pointed out,[1] in connection with cardiac dilatation under chloroform, that the power required to empty the cardiac cavities may be regarded as increasing approximately as the cube of their radius. The effects of chloroform upon the heart isolated from the general nervous system have also been studied by Embley,[2] who found the heart muscle to be very sensitive to chloroform, the drug having an immediate and progressively paralytic effect. He failed, however, to notice any abrupt change in efficiency in isolated hearts. Sherrington and Sowton [3] in an important research upon the action of chloroform on the isolated mammalian heart find that the heart muscle rapidly takes up chloroform offered to it in the vessels of its coronary system, and that the quantities absorbed increase with increasing tension of chloroform in the solution circulating through it. Quite recently, these observers [4] have supplemented their former research. They find that the heart is affected by a much lower concentration of chloroform than are the blood-vessels of the limb or the skeletal muscles of the limb, and that there is an aggravation of the effect of chloroform in saline solution upon the heart, skeletal muscles, and blood-vessels when the chloroform is administered in unoxygenated saline solution containing carbonic dioxide, instead of in oxygenated saline. Whether the drug poisons the muscle cells without entering into chemical combination with their substance; whether some easily dissociable compound is produced; whether the anæsthetic acts as an anti-katalysator on the ferment process at the root of the normal functional activity of the contractile tissue of the heart,—these and other questions must be left for future investigation. To sum up, on this much-disputed point; it may be regarded as established that during chloroform anæsthesia this anæsthetic directly produces a depressing effect upon the heart itself; and that whilst it is true, not only in the physiological laboratory but in actual practice, that respiration generally ceases before cardiac action finally fails,

[1] *Brit. Med. Journ.*, 20th Nov. 1897, p. 1496.

[2] *Trans. Soc. Anæsth.*, vol. v. p. 82; also *Brit. Med. Journ.*, 5th April 1902, p. 821.

[3] *Brit. Med. Journ.*, 18th July 1903; also *Brit. Med. Journ.*, 23rd July 1904, p. 167.

[4] *Ibid.*, 14th July 1906, p. 85.

it is the want of cardiac action which is the essential factor in the causation of death under chloroform.

The **indirect action of chloroform upon the heart** is responsible, according to certain observers, for many of the fatalities which have arisen under this anæsthetic. There are two possible ways in which this indirect action may operate, viz.—(1) by the vapour irritating the sensory nerve-endings within the nasal, laryngeal, tracheal, or pulmonary passages, and so stimulating the cardio-inhibitory centre; or (2) by the blood-borne anæsthetic directly affecting that centre. Dastre, Morat, and numerous French physiologists have attached great importance to the first-named inhibitory effects, and have even gone so far as to speak of a "syncope laryngo-réflexe." Brodie and Russell[1] have also obtained these inhibitory effects, and have laid stress upon the importance of reflexes originating in the pulmonary alveoli. According to Dastre, Franck found that excitation of the laryngeal nerves more easily arrested the heart during chloroform anæsthesia than when no anæsthesia was present. The Hyderabad Commission found that it was impossible to kill animals by direct vagal irritation, no matter whether the anæsthesia were light or profound. By inducing repeated and prolonged vagal arrest of the heart, however, Leonard Hill succeeded in bringing about a fatal issue, the low blood-pressure leading to paralysis of the respiratory centre and death by asphyxia. Within recent years the whole question of cardiac inhibition has been exhaustively studied by Embley,[2] who maintains, as the result of a large number of experiments, that with atmospheres containing more than 2 per cent of chloroform vapour cardio-inhibitory effects are very common, the degree of inhibition being intensified with high percentages. The low blood-pressure thus induced rapidly rose when the vagi were cut, whilst cardiac action again became established (Fig. 7). Slowing or cessation of the heart never occurred in animals in whom the vagi had been divided; whilst the intravenous injection of atropine before chloroform had the same effect as section of the vagi. Embley undertook his investigation with

1 *Journ. of Phys.*, vol. xxvi.

2 "The Causation of Death during the Administration of Chloroform," *Brit. Med. Journ.*, 5th, 12th, and 19th April 1902.

the object of explaining the deaths which take place early in chloroformisation; but his results are not altogether conclusive as to the immediate causes of such fatalities. He finds, for example, that in order to produce fatal cardiac inhibition, the heart must have sustained considerable damage from the direct action of the drug—a state of things hardly comparable to that described in many chloroform accidents in which patients have died during light anæsthesia. Embley denies the proposition of the Hyderabad Commission as to the im-

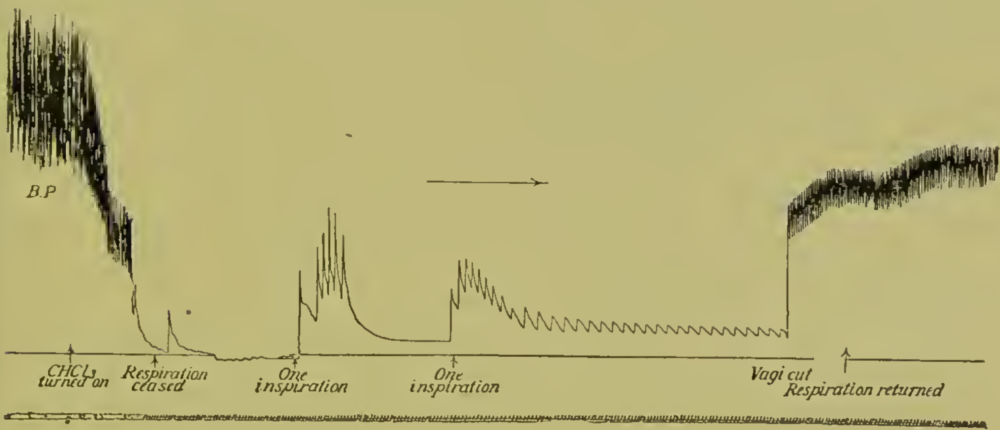


FIG. 7.—(Embley, *Brit. Med. Journ.*, 12th April 1902, p. 890.) Vagi cut after inhibition. Dog, weight 16 lb. Morphine, 0·4 gram. Natural respiration. Blood-pressure tracing only. Chloroform, 6 per cent in air administered. Chloroform started at "on" stopped when inhibition occurred. Gasping liberated the heart twice. Respiration failed after the inhibition occurred. Vagi were then cut. Respiration returned 20 seconds after the vagi were cut, being 190 seconds in abeyance. Blood-pressure had risen again to 74 mm. of mercury-pressure.

possibility of killing animals by vagus excitation. As regards the immediate cause of the inhibition, he is unable to satisfy himself that the latter is due to the action of the chloroform upon sensory nerve-endings, and believes that the increased excitability of the vagus mechanism is due to the action of chloroform on the vagus centre itself, and that the inhibitory action is more intense from being exercised upon a heart whose spontaneous excitability has become diminished. Waller[1] also agrees as to the suddenness with which cardiac arrest may take place from the influence of a concentrated chloroform atmosphere, and the author reproduces, by his kind permission,

[1] *Lancet*, 28th November 1903, p. 1485.

a tracing illustrating fatal chloroform syncope in a cat.[1] Schäfer and Scharlieb's experiments[2] with regard to vagus inhibition are very similar to those of Embley. Whether and to what extent these observations apply to the chloroformisation of human beings, it is at present difficult to say.

It is now generally held that the **action of chloroform upon the vaso-motor centre** is primarily one of stimulation, and that it is not till quite late in chloroform toxæmia that the centre becomes paralysed as the result of the direct action of the

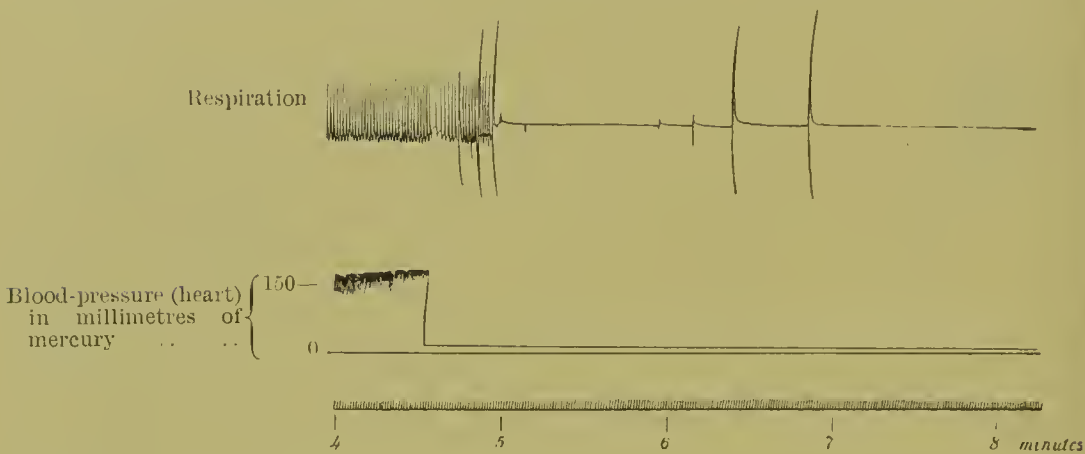


Fig. 8.—An early death by sudden cardiac arrest (primary syncope). Cat under chloroform at 5·75 per cent. No recovery possible. The four gasps apparent on the respiratory record are the terminal anæmic convulsions characteristic of a cardiac death (Waller).

anæsthetic upon it. Embley and Martin's[3] researches have corroborated those of Gaskell and Shore upon this point.

We are now in a position to discuss the **blood-pressure** under chloroform. Whilst it is universally admitted that a marked and progressive fall in pressure takes place, it is still an open question which should be regarded as the essential factor or factors in the causation of this fall. The Glasgow Committee met with a pronounced fall in all their experiments, and attributed it, in some cases at least, to a direct effect of chloroform upon the heart. According to the Hyderabad

[1] Dr. Waller does not give any explanation of this particular death. I introduce the tracing in connection with cardiac inhibition, because I gather from a letter he had written me upon the subject, that he rather favours this explanation.

[2] *Trans. Roy. Soc. Edin.*, vol. xli., Part ii., No. 12.

[3] *Trans. Soc. Anæsth.*, vol. v. p. 82.

Chloroform Commission, however, the characteristic fall of pressure—that which occurred with regular breathing—was due, not to weakening of the heart, but "solely to narcosis of the vaso-motor system."[1] The sudden fall in pressure observed by the Glasgow Committee was regarded by the Hyderabad Commission as due to intercurrent asphyxia. According to Wood and Hare,[2] chloroform produces a double initial effect upon blood-pressure—first a fall due to reflex inhibition of the heart or vaso-motor centre, and then a rise, due probably to reflex vaso-motor spasm. Gaskell and Shore found an initial rise and subsequent fall of pressure, the former being due, according to them, to a stimulation of the vaso-motor centre. As regards the causation of the subsequent fall, these observers found, as the result of a series of ingenious cross-circulation experiments,[3] that it was principally due to the effect of chloroform upon the heart, and not, as the Hyderabad Commission had stated, to an effect upon the vaso-motor centre. They found that injections of the drug into the cerebral arteries caused a *rise* in pressure which was still present at the moment when respiration ceased. They further found that, in other conditions — for example, when the brain arteries were ligatured, when amyl nitrite was injected into the cerebral vessels, and when the intracranial pressure was raised,—the respiratory centre failed before the vaso-motor centre. Leonard Hill[4] has shown, in an important research, that chloroform rapidly abolishes the vascular mechanisms which compensate for the hydrostatic effect of gravity. Thus, when the body of a chloroformed animal is brought from the horizontal to the feet-down position, there is a far greater fall of pressure than occurs in the absence of chloroform anæsthesia. Hill finds that the effect is principally due to a paralytic state of the splanchnic vaso-motor mechanism brought about by chloroform, leading to an accumulation of blood within the splanchnic area. The deeper the anæsthesia the greater is the damaging effect of the drug upon the vaso-motor controlling mechanism. Embley,[5]

[1] *Report*, p. 137.
[2] *Med. News*, 22nd February 1890.
[3] *Brit. Med. Journ.*, 21st January 1893.
[4] *Ibid.*, 17th April 1897, p. 959.
[5] *Ibid.*, 19th April 1902, pp. 955 *et seq.* See also *Trans. Soc. Anæsth.*, vol. v. p. 82.

who has recently done much valuable work in connection with chloroform anæsthesia, agrees with Gaskell and Shore that chloroform stimulates rather than depresses the central vaso-motor system, at any rate for a time, and attributes the fall of pressure to the direct paralytic effect of this anæsthetic upon the heart and arterioles. He admits that the fall may be augmented by slowing of the heart's rate or by the cardiac inhibition which formed the special object of his research. There can be little doubt that the fall of tension under chloroform is often, if not invariably, the result of the action of several factors. Whilst recent researches point to direct cardio-vascular dilatation as the paramount factor (the vessels of the splanchnic area probably being chiefly affected), it is not improbable that in certain cases other factors come into operation. The blood-pressure at any given moment is in fact the expression of numerous conflicting conditions. Some of these conditions tend to raise pressure; for example, chloroform acting directly upon the vaso-motor centre, an asphyxial state of the blood acting in like manner, or the feet-up posture. Others tend to lower pressure; *e.g.* cardio-vascular dilatation, cardiac inhibition, feebleness or arrest of the respiratory pump, and the feet-down (vertical) posture. The net result is always on the side of diminution, the degree of fall being as a general rule roughly proportional to the degree of anæsthesia.

In the course of some observations[1] made in connection with the use of the Vernon Harcourt inhaler (p. 372), Dr. W. J. McCardie subjected himself to chloroformisation by this inhaler, Dr. Dudley Buxton administering the anæsthetic and Mr. Lockhart Mummery recording the blood-pressure by means of a sphygmomanometer. With 1 per cent of chloroform the blood-pressure sank at first slowly, then more rapidly, from 130 mm. of mercury to 110 mm. With 1·5 per cent it fell in ten minutes to 90 mm. and was steady at that point for seven minutes, at the end of which time the proportion of chloroform was lowered to 1 per cent, when the pressure rose again in about six minutes to 105, but did not rise on the average above this point during the next twenty-five minutes though the administration had ceased and consciousness had returned.

The action of chloroform upon the **renal functions** was

[1] *Brit. Med. Journ.*, 14th July 1906, p. 84.

studied some years ago by Thomson and Kemp[1] who found that with this anæsthetic the urinary secretion only became diminished when the general circulation became depressed; that albumen only appeared after prolonged narcosis, and then in but small amount; and that oncometric tracings corresponded with the carotid tracings, and never fell to the base line. The results obtained by Buxton and Levy in a later research agreed in the main with those of Thomson and Kemp. Quite recently Professor W. H. Thompson[2] has shown that in dogs the volume of urine secreted is frequently increased during the early stages of anæsthesia, whilst during full anæsthesia it is always diminished and may even be suppressed. At the end of the administration there is invariably a great increase, which in certain periods may reach four times the normal volume for the same period of time. The total excretion of nitrogen is generally greatly reduced, more so than the quantity of urine. In the course of his experiments he found that the urine secreted during chloroform anæsthesia almost invariably contained less nitrogen per cent than the normal urine. This held good even though the volume of urine was diminished. The excretion of chlorides was much increased both during and after chloroform narcosis. After-albuminuria was met with in a small proportion of the experiments. Many observers believe[3] that chloroform is more damaging to the renal epithelium than ether, as evidenced by the more persistent presence of albumen and casts in the urine after the former anæsthetic.

Reference has already been made (p. 92) to the **degenerative visceral effects** which are liable to result from prolonged chloroformisation. As will be pointed out in the final chapter (p. 604), it is contended by many writers that there is some connection between these degenerative changes and the condition variously described as "**acid intoxication**," "acidıria," "acetonuria," and "delayed chloroform poisoning."

As a result of experiments upon the **quantitative estimation of chloroform in animal tissues** Waller[4] found that, in the case

[1] *New York Med. Journ.*, 18th November and 25th November 1899.
[2] See *Brit. Med. Journ.*, 17th March 1906, p. 608.
[3] *Lancet*, 30th December 1905, p. 1920.
[4] *Brit. Med. Journ.*, Dec. 1901, p. 1859 *et seq.*

of small animals killed by chloroform inhalation, an amount of the drug was obtainable from the body after death equivalent to $\frac{1}{10,000}$ part of the body weight.

With the foregoing data at our disposal we are in a position to commence the consideration of the question, **How does chloroform kill?** It is certain that there is a special risk, at all events in the case of human beings, in the earlier stages of administration, and numerous theories have been advanced to explain this early chloroform syncope. Thus Dastre not only speaks of the primary or laryngo-reflex syncope above mentioned, but he accepts Duret's hypothesis of an early "bulbar syncope," which is supposed to result from a very strong vapour stimulating and then paralysing the cardio-accelerator centre of the cervico-dorsal cord, whilst the cardio-inhibitory centre is in a state of excitement and brings the heart to a standstill. There is excited cardiac action; the blood-pressure, raised at first, quickly falls; the heart then slows and finally ceases, the slowing being due to paralysis of the accelerator centres of the cord, and the syncope to a direct and excitant action of the chloroform upon the inhibitory mechanism. As indicated above, Embley's researches concerning the causation of sudden death during the administration of chloroform also point to a direct action of this anæsthetic upon the cardio-inhibitory centre. He believes that the vagi are most active during the induction stages; that concentrated chloroform atmospheres act prejudicially, through the medium of the blood, directly upon the vagus centre; and that the greater the cardiac depression which has been produced by chloroform, the greater the liability to vagus arrest. Schäfer and Scharlieb also attach importance to vagal inhibition as a factor in early chloroform syncope.

Owing to the fact that the experimental physiologist cannot reproduce many of the clinical phenomena which play such an important rôle in the chloroform accidents of practice, we shall not be in a position to complete the consideration of the question before us till we have studied the nature and origin of these clinical phenomena (see p. 400). The physiological facts which have been embodied in this chapter merely give us an insight into the mechanism of death from simple

chloroform toxæmia. The introduction into the circulation of poisonous quantities of chloroform quickly brings about cardio-vascular paralysis, the central and most important factor in this toxic state. As we shall subsequently see, many, and perhaps most, of the chloroform accidents of practice take place, not during simple but during complex chloroform anæsthesia (p. 41); not merely from an overdose of the drug, but from some intercurrent and often unrecognised asphyxial state, which, in conjunction with the presence of chloroform within the circulation, quickly leads to fatal cardiac paralysis.

So far as we have gone, then, it would seem that we have in chloroform a drug which is a powerful protoplasmic poison,

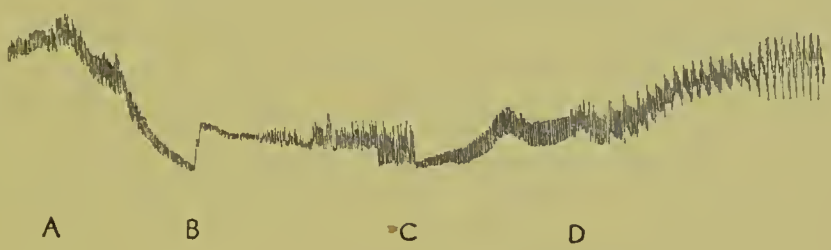


FIG. 9.—Cannula in carotid. Dog. Shows recovery from chloroform syncope brought about by rhythmic compression of thorax in horizontal posture. Abdomen was now and again gently compressed to fill heart. Shows that respiratory waves disappear as arterial pressure falls (A—B), and that natural breathing reappears when arterial pressure becomes raised during the period of asphyxia (C—D) which follows after the period of artificial respiration (B—C). Also shows how the artificial pressure can be mechanically maintained by artificial respiration. Blood is forced into the right heart and lungs by abdominal compression, and driven through lungs and left heart into aorta by thoracic compression. A, Chloroform pushed. B, Artificial respiration: alternate compression of abdomen and thorax. C, Artificial respiration left off, followed by asphyxial rise. D, Commencement of natural breathing.

which, when given in toxic quantities, leads to death of the organism, not because it paralyses respiration—for were it merely a respiratory depressant, artificial respiration would be invariably successful in averting death—but because, as recent researches have shown, it markedly depresses the circulation. It is this circulatory depression which renders it difficult to resuscitate patients. The fact that an overdose of chloroform generally paralyses respiration before the heart's action finally ceases must not be allowed to overshadow the more important fact that prior to and during the respiratory failure the heart has, in many cases, ceased to circulate blood through the

organism. Whether in true chloroform toxæmia the fatal circulatory failure is principally (*a*) a failure of cardio-vascular origin due to chloroform directly affecting the musculature of the vascular system *as a whole*; whether it is principally (*b*) a failure of cardiac origin, the chloroform directly affecting the *cardiac muscle relatively more than the walls of the arteries and arterioles*; whether it is principally (*c*) a failure due to the action of chloroform upon the *nervous mechanism which controls cardiac action*; or whether it is principally (*d*) due to a paralysis of the *vaso-motor mechanism*—we cannot at present positively say.

The tracing shown on p. 133 (kindly presented to the author by Dr. Hill) is of interest in connection with the application of remedial measures in chloroform syncope.

D. OTHER AGENTS CAPABLE OF PRODUCING GENERAL ANÆSTHESIA

Comparatively few researches have been conducted with the other general anæsthetics to which incidental reference has already been made (p. 40); and the reader will therefore find in the clinical part of this work (p. 447 *et seq.*) most of the information which is at the present time available concerning the action of these substances. There are, however, certain theoretical and experimental data which call for brief notice in the present chapter.

The properties of **ethyl chloride**, an anæsthetic which has recently come into extensive use for short operations, were investigated by the Glasgow Committee, who found that it rapidly produced general anæsthesia. In one case respiration ceased, and in another general convulsions supervened. Kemp[1] also came to similar conclusions recording stertor, difficult respiration, tremors, and convulsive movements of the legs. According to McCardie,[2] Koenig found that the rapidity of narcosis depended on the degree of dilution with air. A mixture of 10 per cent of ethyl chloride vapour with 90 per

[1] *New York Med. Journ.*, 2nd Dec. 1899, p. 804.
[2] *Lancet*, 4th April 1903, p. 953.

cent of air caused narcosis in small animals at the end of six or seven minutes. 50 per cent mixtures rapidly caused narcosis lasting for some minutes. Pure ethyl chloride vapour caused regular and rapid lowering of arterial pressure ending in respiratory and cardiac arrest. These effects were observed in dogs and monkeys. McCardie also states that Wood and Cerna found that ethyl chloride caused augmentation of the respiratory movements and lowering of blood-pressure during narcosis. The rate of the heart-beat was at first decreased and then increased. In some experiments which he conducted, W. Webster[1] found that small doses of ethyl chloride increased the force and depth of respiration, while large doses depressed this function. With very large doses the breathing ceased some considerable time before the heart stopped. With small doses the blood-pressure rose slightly, but with large doses it fell, these effects occurring not only with intact but with cut vagi. Circulatory depression is said to be chiefly due to the effect of the drug upon the heart.

According to Dastre, Rabuteau found that **ethyl bromide,** like other anæsthetics, arrested germination, but that its vapour was more poisonous to plants than that of ether. Dastre states, moreover, that whilst the bromide is undoubtedly a powerful anæsthetic, it does not, like chloroform, lead to "primary syncope," and he believes that this difference is due to the drug being less irritating and caustic in its local action. He explains the usual absence of excitement by the supposition that the cerebral hemispheres, bulb, and cord are peculiarly sensitive to the action of the drug. The effects produced upon blood-pressure by bromide of ethyl have been investigated by Ginsberg. According to Cole,[2] Ginsberg, who experimented upon rabbits and dogs, found that small doses of ethyl bromide, sufficient to produce anæsthesia, did not lower blood-pressure, but that large doses caused a fall of pressure with irregular pulse and rapid respiration. Death was due to respiratory failure which preceded cardiac failure. Ginsberg is stated to have ascribed the cardiac acceleration to stimulation of automatic cardiac centres or of peripheral accelerator nerves,

[1] *Bio-Chemical Journal*, June 1906. Abstracted in *Lancet*, 14th July 1906, p. 106.

[2] *Brit. Med. Journ.*, 20th June 1903, p. 1423.

and the fall of blood-pressure to paralysis of peripheral vaso-motor nerves. He is also stated to have found that the vagus, the vaso-dilator centres, and the peripheral vaso-dilator nerves were not affected by ethyl bromide. In the course of an experimental inquiry, Cole[1] found that under ethyl bromide the strength of the heart's contractions was diminished, not only with intact but with divided vagi, and that the vagus endings in the cardiac ganglia were paralysed. The rate of the heart's action was increased. Rigidity of the skeletal muscles was observed even during deep coma. He disagrees with Ginsberg as to the effects of ethyl bromide upon the vaso-motor system, for he failed to find any evidence of the drug paralysing peripheral vaso-constrictor fibres. W. Webster,[2] in the course of his experiments, found that ethyl bromide produced the same physiological effects as ethyl chloride (*vide supra*). He disagrees with Cole as to the action of this anæsthetic upon the vagus terminals, maintaining that full vagus effects can be obtained with an animal completely anæsthetised by ethyl bromide.

Ethidene dichloride was experimentally studied by the Glasgow Committee,[3] who found that under its influence blood-pressure fell, though not to the same extent as in the case of chloroform. They found, moreover, that it had not nearly such a depressant action upon the heart as chloroform, so that it might be considered a safer anæsthetic.

The Glasgow Committee also tested the effects of numerous other organic liquids.[4] Thus **Dutch liquid** was found to produce convulsions before true anæsthesia appeared; **butyl chloride** caused breathing to cease very soon after anæsthesia had become established; **acetone** set up only slight effects in a frog, even after a long administration; and **benzene** caused struggling and cardiac weakening, although the latter effect was not so marked as with chloroform. As regards the first named of these anæsthetics—Dutch liquid—this had previously been experimentally studied by Snow, Simpson, and Nunneley, and actually used in practice.

The Committee also tested the anæsthetic properties of

[1] *Op. cit.* [2] *Op. cit.* [3] *Brit. Med. Journ.*, 4th Jan. 1879, p. 1.
[4] *Ibid.*, 4th Jan. 1879, p. 1.

isobutyl chloride and **methyl chloride**. With the first-named drug rabbits and dogs were completely anæsthetised in from three to five minutes, and respiration was unaffected even after half an hour's administration. With human beings, however, isobutyl chloride produced excitement and proved itself to be but an imperfect anæsthetic.[1] With methyl chloride the Committee were unable to obtain any other effect than drowsiness, the rabbits on whom they experimented preserving their reflexes even after a prolonged administration.

Tetrachloride of carbon has been experimentally studied by Laffont, Rabuteau, and Morel. Frogs are slowly anæsthetised by it, and recover slowly from its influence. It is stated that in warm-blooded animals a powerful effect is produced, excitement and muscular spasm—both tonic and clonic—appearing, whilst during the period of anæsthesia the heart beats rapidly and the blood-pressure falls.

The physiological properties of **bichloride of methylene** have been investigated by Regnauld,[2] Villejean, and Richet. According to Dastre, the first two of these observers found that whilst anæsthesia came about very rapidly, the muscular excitement which the drug produced was so violent that the agent could not be regarded as an anæsthetic in the ordinary sense of the word. In addition to general muscular spasm of a tetanic character, epileptiform and choreiform movements appeared, and these persisted even after the anæsthetic effects had passed off. Richet has also administered bichloride of methylene to lower animals, and states[3] that the muscular phenomena resemble those of asphyxia, whilst the anæsthesia disappears very rapidly. The properties of the anæsthetic liquid introduced under the name of "bichloride of methylene" or "methylene" by Richardson will be discussed in the clinical section of this work (p. 468).

Acetate of ethyl, or acetic ether, has been used to anæsthetise frogs. It is stated that it is decomposed in the blood into acetate of soda and alcohol, and that anæsthesia is produced

[1] *Brit. Med. Journ.*, 21st June 1879, p. 923.
[2] *Soc. de Biol.*, 22nd March 1884.
[3] *Dict. de Physiologie.*

by the latter (Dastre); there is, however, but little ground for this assertion.

The anæsthetic properties of **carbonic acid** gas have long been known to physiologists; and the interesting experiments of Mojon, Ozanam,[1] Paul Bert, and Gréhant[2] have added much to our knowledge concerning this body. The last-named observer found that the best results were obtained with mixtures containing as much as 45 per cent of carbonic acid and a proportion of oxygen equal to or in excess of that present in atmospheric air.[3] With such mixtures rabbits were deeply anæsthetised in two minutes, and it was possible to maintain anæsthesia for a prolonged period. Respiration was much reduced in frequency, but its rhythm was unaffected. Blood analyses showed that the oxygen percentage remained constant, but that the CO_2 was greatly increased, oscillating between 80 and 90 per cent. With less than 45 per cent of carbonic acid in the mixture breathed, it is stated that anæsthesia did not supervene. Richet[4] points out that carbonic acid is not eliminated as rapidly as many other anæsthetics, because, whilst within the organism, it plays the part of an acid and combines with the alkalies of the blood and tissues.

The effects produced by the **indifferent gases** will be subsequently studied (p. 456).

It has been shown that when introduced into the veins, **chloral** is capable of producing general anæsthesia (Oré), but there are considerable risks in such a procedure.[5]

Finally, a few researches have been conducted with mixtures of anæsthetics, and with mixtures of anæsthetics with liquids not necessarily possessed of anæsthetic properties. Thus the **A.C.E. mixture** (p. 466) has given results very similar to those of chloroform. Kemp found[6] that when the vapour of this mixture was administered to dogs with 95 per cent of air, the carotid tracings closely resembled those obtained with chloroform, and that when the air-supply was lessened, very pronounced chloroform effects appeared. Leonard Hill

[1] *Académie des Sciences*, 25th Feb. 1858.
[2] *Soc. de Biologie*, 29th Jan. and 12th March 1887.
[3] See Dastre, *op. cit.*
[4] *Dict. de Physiologie.*
[5] See Dastre.
[6] *New York Med. Journ.*, 25th Nov. 1899.

found that when a small quantity of the A.C.E. mixture was introduced into the jugular vein of an animal whose heart had been enclosed in a tennis ball connected with a piston recorder, the tracing showed an immediate ether effect, and a subsequent chloroform effect. Upon the kidney Kemp observed the same effects as those produced by chloroform, provided that the open method was used. When a semi-closed method of administration was adopted, the effects resembled those of ether. The renal secretion was more copious than with pure ether, but less copious than with chloroform.

PART II

PRELIMINARY CONSIDERATIONS BEFORE ANÆSTHETISATION

CHAPTER V

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN ORDINARY OR ROUTINE CASES

IN opening the clinical or practical part of this work it may be well to clearly define certain terms which will be constantly employed. The term **anæsthetic** will be used to include, not only the simple or fundamental substances, such as nitrous oxide, ether, etc., whose properties have been considered in Part I., but also all stable mechanical **mixtures** of these bodies, such, for example, as the C.E. mixture—a name given in this work to a mixture of 2 parts (by volume) of chloroform to 3 parts of ether. The term **sequence** or **succession** will be used when two or more anæsthetics are administered consecutively. We shall, for example, speak of the nitrous oxide-ether sequence, the C.E.-ether-chloroform succession, etc. When an anæsthetic, mixture, or succession is administered according to a particular but broad principle, we shall speak of this or that **system** of administration. To Snow, for example, belongs the credit of introducing the percentage system of chloroformisation; to Andrews that of administering oxygen with nitrous oxide; to Clover that of administering ether with a limited air-supply. The term **method** will be restricted to the actual means by which the anæsthetic, mixture, or succession is administered. For example, Clover's system of employing nitrous oxide and ether in succession may be put into force by the use of different **methods.** Andrews' principle or system of obtaining non-asphyxial nitrous oxide anæsthesia may be carried into effect by employing Paul Bert's method. Lastly, it will also be convenient to speak occasionally of certain **modifications in methods.**

The anæsthetist of to-day has at his disposal not only a considerable number of anæsthetics, mixtures of anæsthetics, and successions of anæsthetics, but also a great variety of methods of administration. Putting aside for the present certain exceptional circumstances, to which reference will subsequently be made, it may be said that the practice of employing one anæsthetic for all cases must now be regarded as belonging to a bygone time. To ensure success in inducing and maintaining general anæsthesia we must vary our anæsthetic and our methods of using it, according to the exigencies of the case with which we have to deal.

Of the simple or fundamental anæsthetics referred to in Part I., there are only four which need engage our attention on the present occasion, viz. :—

Nitrous Oxide,
Ether,
Chloroform, and
Ethyl Chloride.

Of the mixtures, that known as

The C.E. mixture

is worthy of notice. And of the successions or sequences of anæsthetics, the following are the most important and useful :—

The Nitrous Oxide-Ether sequence;
The Ethyl Chloride-Ether sequence;
The C.E.-Ether sequence;
The Nitrous Oxide-Ether-Chloroform sequence;
The Nitrous Oxide-Ether-C.E. sequence; and
The C.E.-Chloroform sequence.

In attempting to formulate principles for the selection of anæsthetics, we have, in the first place, to decide what means should be adopted for inducing and maintaining anæsthesia in **ordinary or routine practice.** With this section of the subject the present chapter will deal. Next, we have to decide what modifications in this routine practice are advisable when

anæsthetising patients belonging to this or that type, or suffering from this or that condition. This part of the subject will be discussed in Chap. VI. And in the third place, it is necessary to indicate the special lines of practice which should be pursued in administering anæsthetics for certain operations, procedures, or conditions. This part of the subject will be considered in Chap. VII.

In deciding upon the means to be employed for producing anæsthesia in ordinary or routine practice, one of the most important considerations should be the **safety of the patient.** It is clearly the duty of all who have not become specially familiar with some less safe anæsthetic to choose the safest of those which are available, always provided that its use is free from inconvenience to the surgeon and from discomfort to the patient. Two questions hence present themselves: (1) Which is the safest anæsthetic for brief operations not requiring total muscular relaxation? and (2) Which is the safest anæsthetic for operations demanding profound or continuous narcosis? It will be convenient to consider these questions separately.

(1) It is now universally admitted that nitrous oxide is the safest general anæsthetic known. When administered with a proper percentage of oxygen, in order to eliminate the asphyxial element, its inhalation is practically free from risk to life. Almost equally good results may be obtained with air as the oxygenating medium. Even when pure nitrous oxide is given by any one familiar with its use the risk to life is so slight as to be almost negligible. In addition to its being the safest anæsthetic, nitrous oxide is not unpleasant to inhale; it rapidly destroys consciousness; and its administration is rarely followed by unpleasant after-effects. On the other hand, the heaviness of its storage cylinders, the comparative lightness of its anæsthesia, the tendency to muscular rigidity, movement, and asphyxial accompaniments during the administration of the pure gas, and the somewhat lengthy experience required to obtain good results in all cases, combine to limit the employment of this valuable anæsthetic.

Given that the patient is of a suitable type, that the operation is one in which slight reflex movement would not be inconvenient, and that the apparatus required for the

administration would not incommode the surgeon, there is no form of anæsthesia with which we are acquainted which is so perfect as that of nitrous oxide and oxygen. Many small operations, such, for example, as the removal of small tumours, the slitting up of sinuses, the dressing and examination of wounds, may usually be performed under this anæsthetic without causing the slightest after-effects, always provided that the patient be properly prepared, and that the other details connected with this form of anæsthesia be observed.

Within recent years ethyl chloride has come into extensive use for brief surgical operations; its great advantages over nitrous oxide being that it is far more portable, more manageable, and easier to administer. But from the somewhat numerous accidents that have occurred under its influence there is good reason to believe that the risk attending its administration is considerably greater than was at first supposed. It is highly probable, indeed, that the near future will witness a considerable limitation rather than an extension in its use. At the same time ethyl chloride is a useful anæsthetic for certain cases, provided that it be administered by some one thoroughly conversant with the principles of anæsthetisation.

(2) Nitrous oxide and ethyl chloride being inapplicable for major surgical operations, it is important that every member of the profession should know which is the safest routine agent when muscular relaxation or protracted narcosis is needed. It may now unhesitatingly be affirmed that ether enjoys this position.

Statistics as to the relative safety of ether, chloroform, and other agents are unquestionably open to grave fallacies, and must be accepted with caution. So-called "deaths under anæsthetics" are often deaths partly or wholly attributable to other causes than the influence of the anæsthetic itself, and, conversely, fatalities which should be properly ascribed to anæsthesia are often either never reported or regarded as due to "surgical shock," "collapse," etc. Again, statistics generally ignore those cases of fatal bronchitis and pneumonia which undoubtedly occasionally follow the use of anæsthetics, and particularly ether, and which should in all fairness be included in any statistical inquiry. Moreover, the personal element—the experience of the administrator or administrators in any given series of cases—is often not taken into account. And lastly, it must be remembered that desperate cases are often

regarded as unsuitable for chloroform, so that ether is chosen for them, with the result that the ether death-rate is thereby unfairly increased. Still, with all these objections to statistics, there can be no doubt that they have their value. Whilst they may be regarded as roughly indicating the relative risks of ether, chloroform, etc., during anæsthesia, they cannot be accepted as representing the true relative death-rates.

The late Sir B. W. Richardson [1] obtained records of 35,162 chloroform administrations with 11 deaths, giving a death-rate of 1 in 3196, and of 8431 ether administrations with but 1 death.

It is stated [2] that in the Crimean War there were 20,000 chloroform administrations with but 2 deaths.

Dr. Julliard [3] of Geneva has collected, from various reliable sources, records of no less than 839,245 ether and chloroform administrations. The following table shows the relative frequency with which chloroform and ether were used, and the relative death-rate :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	524,507	161	1 in 3258
Ether . . .	314,738	21	1 in 14,987

Dr. Ormsby of Dublin has put on record [4] the following administrations :—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	152,260	53	1 in 2873
Ether . . .	92,815	4	1 in 23,204
Chloroform with ether	11,176	2	1 in 5558
"Bichloride of methylene" .	10,000	2	1 in 5000

At the 1890 meeting of the German Surgical Society it was resolved to collectively investigate the relative safety of anæsthetics. 24,625 cases were reported [5] during six months. Of these there were 22,656 chloroform administrations, with 6 deaths, 2 of which, however, occurred

[1] *Asclepiad*, Jan. 1892.
[2] Dastre, *op. cit.*
[3] *L'Éther est-il préférable au Chloroforme?* Par M. le Professeur Julliard de Genève. (Extrait de la Revue Médicale de la Suisse romande, No. 2, février 1891.)
[4] *Brit. Med. Journ.*, 14th April 1877, p. 446.
[5] See Gurlt's Summary, *Archiv für klin. Chirurgie*, vol. xlii. pp. 282 and 301.

from other causes than the anæsthetic. This would give a chloroform death-rate of about 1 in 5500.

Körte[1] has collected records of 133,122 chloroform administrations with 46 deaths, giving a death-rate of 1 in 2894 cases.

At St. Bartholomew's Hospital,[2] during the years 1875-1900, there were 80,255 administrations of chloroform, ether, and "gas and ether"; and the following table shows the fatalities and death-rates:—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	42,978	33	1 in 1300
Ether and "Gas and Ether" .	37,277	4	1 in 9319

According to these figures, which are perhaps the most reliable at our disposal, it would appear that ether is about seven times as safe as chloroform. The tendency to a too high ether death-rate from the inclusion amongst the ether cases of desperately bad subjects is counterbalanced to a greater or less extent by a tendency to a too low death-rate from the exclusion of cases of pulmonary complications referable to ether. It is interesting that the ratio seven to one corresponds to that obtained by Waller as the expression of the relative toxicity of chloroform and ether (p. 70).

If we combine Dr. Julliard's statistics with those of Dr. Ormsby, we obtain the following results:—

Anæsthetic.	Total No. of Administrations.	Total No. of Deaths.	Death-rate.
Chloroform . .	676,767	214	1 in 3162
Ether	407,553	25	1 in 16,302

According to these figures ether is, roughly, more than five times as safe as chloroform.

With the above statistics before us we shall probably not be far wrong in assuming that, under the circumstances mentioned, **ether is about six times as safe as chloroform**; in other words, with a heterogeneous assortment of anæsthetists, patients and operations, and with ether and chloroform as the anæsthetics, the risk to life is about one-sixth as great with the

[1] *Deutsche med. Zeit.*, 12th Feb. 1894.
[2] See a letter by Mr. Roger Williams, *Lancet*, 7th June 1902, p. 1643.

former as with the latter agent. It is therefore clear that, in the absence of special circumstances, the anæsthetist is morally bound to employ ether in preference to chloroform for the majority of cases in ordinary surgical practice. Amongst the special circumstances that may justify him in employing some other anæsthetic for routine use may be mentioned: (1) extremes of temperature rendering the use of ether impossible; (2) the impossibility of obtaining, carrying about, or keeping in order the requisite apparatus for administering ether; and (3) special familiarity with the administration and effects of some other anæsthetic. These special circumstances will be discussed below.

Nitrous oxide and ether may be regarded as the two anæsthetics which should generally be employed in the **ordinary course of surgical practice**; the one for very short operations, the other for those of longer duration. The system and method by which the former should be administered must depend upon the views and experience of the anæsthetist. For example, by administering air or oxygen with nitrous oxide, the anæsthesia may be extended far beyond that limit, which is attainable with nitrous oxide alone (see pp. 294 and 306). The same may be said with regard to ether. Whilst the "close" system of administration (p. 329) is undoubtedly the best for general use, the want of a special appliance or the lack of experience in its employment may render the "semi-open" system the most appropriate (p. 326). For example, in country districts, in which a practitioner is seldom called upon to give an anæsthetic, the administration of ether from some simple form of cone, at the apex of which a sponge is placed for the reception of the ether, may meet the case. Although inferior in many respects to other methods, this one certainly has the merits of safety and simplicity. The nitrous oxide-ether sequence (p. 479), the ethyl chloride-ether sequence (p. 484), and the C.E.-ether sequence (p. 487) have certain advantages over simple etherisation, the most conspicuous being the prevention of the initial taste of ether. With the two former, moreover, excitement and struggling may be eliminated.

In conclusion, a few words may be said as to the **exceptional circumstances** under which certain anæsthetics or

mixtures of anæsthetics are permissible for routine use (*vide supra*).

(1) In extremely cold climates it may be difficult to vaporise ether with sufficient rapidity to produce smooth anæsthesia. On the other hand, in tropical temperatures the use of ether, which boils at about 95° F., may be difficult or impossible. Under such circumstances as these, chloroform or some such mixture as the C.E. mixture may be requisite.

(2) When it is impossible to obtain a proper ether inhaler; when portability is a matter of great moment, as on the battlefield; or when from climatic conditions or other causes an ether inhaler cannot be kept in good order, the C.E. mixture or even chloroform must be employed. The great portability of ethyl chloride will probably lead to its extensive use for minor operations in military surgery.

(3) After many years of experience either with some special chloroform and ether mixture or with chloroform itself, such skill may be acquired that the administrator's results, so far as the avoidance of fatalities is concerned, may approach or possibly equal those of the ardent supporter of ether. It is doubtful, however, whether the exclusive administrator of chloroform can ever become so perfect in its administration as to be able to wholly eliminate the risk which attaches to the early stage of chloroformisation. But by what may be termed the "fine adjustments" in anæsthetisation it is possible for a practised anæsthetist to avail himself of the undoubted benefits of chloroform for lengthy operations without incurring the chief risk of this anæsthetic, *i.e.* the risk of the induction period. He employs, for example, the nitrous oxide-ether sequence, the ethyl chloride-ether sequence, or the C.E.-ether sequence for the induction stage of anæsthesia, and then changes to chloroform for the remainder of the administration. By such successions of anæsthetics the advantages of certain agents are obtained, whilst the disadvantages of others are eliminated. It is not suggested that these complicated sequences are suitable for routine use by the comparatively inexperienced administrator. They are simply referred to here as instances of recent developments which have taken place in this branch of practice. They can, in fact, only be successfully

used after experience has been gained with each of the agents included in the sequences.

As the C.E. mixture is undoubtedly one of the best anæsthetics for a large number of cases in major surgery, one is often asked: Why should not this mixture, which is not unpleasant to inhale, which is certainly safer than undiluted chloroform, and which can be administered by a simple form of apparatus, be used for routine work; and if it be suitable for *bad* subjects, why should it not, *à fortiori*, be suitable for good ones? The fact is that for its safe administration considerable experience is needed; but when once this has been gained it may certainly be used as a routine anæsthetic. The explanation of the fact that the C.E. mixture answers better, as a rule, in unhealthy than in healthy subjects is that with the latter excitement, struggling, and rigidity are more likely to arise.

CHAPTER VI

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN PARTICULAR AND EXCEPTIONAL CASES

PART I.—THE STATE OF THE PATIENT AS A FACTOR

A careful consideration of the state of the patient is essential, not only in deciding upon the anæsthetic and the method of its administration, but in forming an opinion as to the probabilities of certain difficulties or dangers arising during the induction or maintenance of anæsthesia. The typically healthy patient is by no means necessarily the best subject for an anæsthetic. It is a popular fallacy to imagine that, because the heart-sounds are normal and no visceral disease can be detected, the anæsthesia will run a perfectly normal and straightforward course. On the contrary, the best subjects for anæsthetics are to be found amongst comparatively feeble persons. Were it merely a question of the supervention of toxic phenomena, the matter would be a simple one, for the strongest and healthiest patients would, as a general rule, be less liable to give cause for alarm than their more weakly fellows. Such, however, is not the case. It is, of course, true that asthenic subjects and those with morbid states of the heart or lungs will not be able to hold out against any given strain as long as stronger persons. But if we wish to avoid accidents we must study not so much the threatening symptoms themselves as the causes upon which they depend. From the point of view of the anæsthetist, patients may be arranged in classes or types, according to the presence or absence of the conditions enumerated and considered in this chapter.

It is a curious and important fact that patients whose general condition is unsatisfactory are usually far more tolerant of a comparatively light anæsthesia than vigorous subjects. Whilst a healthy child or adult may require large quantities of a given anæsthetic in order that inconvenient reflex movement or abdominal rigidity may be prevented, the chronic invalid, the bronchitic or asthmatic sufferer, or the patient with advanced morbus cordis and a degenerated vascular system, will often remain completely passive to surgical procedures even though a brisk lid-reflex be present.

A. SEX AND AGE

Sex.—Sex has a distinct, though probably only an indirect influence upon the effects produced by general anæsthetics. Women certainly pass more easily than men into deep anæsthesia—a fact which may be explained by their physique being, as a rule, inferior to that of men (*vide infra* **D**). Men with feebly-developed muscular systems take anæsthetics very much in the same manner as women, and women of masculine type display similar symptoms to those of men. Emotional disturbances are commoner in women than in men.[1]

Age.—Similarly, age has of itself no intrinsic influence in modifying the effects produced by anæsthetics. It is rather the presence, at different periods of life, of different physical and other conditions which must be considered. The invariable use of chloroform, for example, for patients between certain ages, and of ether for patients at other periods of life, cannot be regarded as rational. General anæsthetics may be given to patients of all ages. Infants but a few hours old may be safely anæsthetised; and anæsthetics have been successfully administered to centenarians.

A few words may not be out of place concerning the general **management of children** about to be anæsthetised. Kindness, gentleness, and good temper are important elements in the success of an administration. Children should never

[1] See p. 402. Of the 210 chloroform fatalities referred to, only 59 or 60 occurred in females.

be deceived or entrapped. The less said to them by their relatives and friends the better. The alarm sometimes displayed by these little subjects is almost invariably due to the misguided action of sympathetic parents and friends who, by their unusual conduct and expressions, have betrayed their apprehension. On the day of the operation there should be as little deviation as possible from the child's usual routine. If the relatives and friends can be persuaded to adopt such a course they should altogether absent themselves immediately before and during the administration. A little "wholesome neglect" is often an excellent prescription, both before and after anæsthesia. When, as sometimes happens immediately before an anæsthetic is given, a child is surrounded by an agitated crowd of relations, all speaking at the same time, a state of alarm is not unlikely to arise. It is generally quite unnecessary to tell children beforehand that anything unusual is about to happen; but with intelligent children of six and upwards, it is often a good plan to say that they "are going to have something to smell which will make them better" or "take away their pain," as the case may be. Generally speaking, the administration may be begun whilst the little patient is lying in bed (p. 156), and it is often useful to first spray some Eau de Cologne on the Skinner's mask and gradually add the C.E. mixture whilst the child counts aloud. In this way most small children may be anæsthetised without distress.

The upper air-passages of **infants and young children** are so sensitive that ether often causes some irritation and reflex "holding of breath." This has led many to prefer chloroform, which is certainly inhaled with comparative ease by children. It is a mistake, however, to suppose that children are not so susceptible as adults to the toxic effects of this agent, and that with them fatalities are practically unknown. It is true that children inhale chloroform freely, and that they are not as liable as adults to certain forms of respiratory embarrassment. It is certain also that children may be rescued from conditions of respiratory and circulatory depression which in adults would be attended by more immediate risk to life. Children are, however, occasionally placed in considerable peril by chloroform, and more fatalities under this anæsthetic have

been recorded than might be imagined.[1] Although chloroform is apparently better borne than ether by children, it nevertheless possesses certain special disadvantages in these subjects. It not unfrequently induces an extremely tranquil and sleep-like respiration which deprives the administrator of the most important means of knowing how deeply his patient is anæsthetised. This reason is alone sufficient to warrant us in the use of ether in some form or another for very young subjects. Moreover, the experience of recent years would seem to indicate that chloroform is far more liable than ether to be followed by certain peculiar toxic after-effects to be subsequently discussed (p. 604). Nitrous oxide is not an appropriate anæsthetic for children under three or four years of age, although, if given with suitable percentages of oxygen, it answers far better than when otherwise administered. The fragile thoracic parietes seem to be unable, in many cases, to efficiently meet the demands made upon them by the necessary valves and other parts of the inhaler. Pure nitrous oxide may rapidly bring about, in a small child, a very undesirable state of asphyxia. For **infants in arms** the method of etherisation described on p. 328 answers admirably. The directions there given should be closely followed. If the C.E. mixture be preferred—and it is perhaps preferable for operations of over ten or fifteen minutes' duration—it should be administered from a Skinner's mask (p. 462). If chloroform be used, it must be given in drops from a Skinner's mask; or by means of a Junker's inhaler, the flannel mask of which should never be closely applied. The administration of chloroform to children during natural sleep will be subsequently considered (p. 400). For children of from **eighteen months to four years** the C.E.-ether sequence may be employed as described on p. 489 with good results, and is particularly appropriate for comparatively short operations such as that of circumcision. Some authorities [2] speak well of ethyl chloride for brief operations

[1] Comte, who has collected records of 232 chloroform fatalities, found that, of this number, 21 occurred in children. Weir stated (1890) that no death had been recorded under ether given to patients under twelve years of age. *New York Med. Journ.*, 1st March 1890.

[2] See Dr. W. J. McCardie's article: *Brit. Med. Journ.*, 17th March 1906. See also *Lancet*, 25th November 1905, p. 1542. Miss Flora Murray records 150

upon small children; but this anæsthetic has hardly been in use for a sufficient length of time to warrant any definite pronouncement as to its suitability for such cases. For comparatively protracted operations upon patients of this class the C.E.-ether-C.E. sequence (p. 500) may be employed, or the C.E. mixture, sprinkled upon a Skinner's mask, may be used throughout. Children over four years of age may generally be induced to count aloud during the slow administration of the C.E. mixture. As there is no objection (p. 246) to transferring small children, when partially anæsthetised, from one spot to another, the administration may with advantage be started whilst the little patient is lying in bed. The time taken to induce anæsthesia in children is often unexpectedly long, owing to the frequency of breath-holding. Crying children are, for obvious reasons, quickly anæsthetised. When once anæsthesia has become established, it may, as a rule, be maintained by comparatively small quantities of anæsthetic, always provided that the act of vomiting (which is very liable to accompany light degrees of anæsthesia in children) would in no way inconvenience the surgeon. Children of **five, six, or seven years** of age may also be anæsthetised whilst lying in bed, and under such circumstances all complicated sequences should be avoided as likely to cause alarm. A Skinner's mask and a drop bottle containing C.E. mixture can easily be carried in the pocket, and these simple appliances will be all that is necessary, at all events, for inducing anæsthesia. Should another anæsthetic be subsequently required, it can be substituted when the child has been carried to the operating table.

Children of **eight years** and upwards may generally be successfully anæsthetised upon the operating table, and under these circumstances the nitrous oxide-ether, the nitrous oxide-ether-chloroform, or the nitrous oxide-ether-C.E. sequence may be used, provided that all preparations be made before the patient enters the room. One great advantage of nitrous oxide in anæsthetising children is that, if properly administered,

administrations of ethyl chloride to infants under one year of age. She met, however, with arrest of breathing in four cases. In two of these, tongue traction and artificial respiration were needed.

it is generally breathed without resistance. If, however, the child should commence to cry, the crying will be but momentary. Ethyl chloride has a much more distinct odour than nitrous oxide, and has not, in the author's hands, proved quite so satisfactory as an induction agent, at all events from the point of view of the patient. If the child be actually crying or hopelessly recalcitrant when the moment of administration arrives, ethyl chloride seems to be specially serviceable. As regards the routine use of this anæsthetic for brief operations upon children of the age in question, all we can say at present is that the results which have been obtained seem to be distinctly encouraging. It is, however, certainly inferior to other agents for comparatively lengthy cases.

When, as in **abdominal operations**, it is essential to maintain deep chloroform or C.E. narcosis in order to avoid all chances of "straining," the resources of the anæsthetist may be severely taxed. The skill of an administrator may, in fact, be gauged by the percentage of abdominal cases in children which he can carry through without straining or vomiting occurring upon the operating table (see pp. 211 and 519).

Children appear to be more liable than adults to "**acid intoxication**" or "acidosis"—a state which occasionally arises after a general anæsthetic and particularly after chloroform (Chap. XX. p. 604). When, from the presence of an excess of acetone in the urine and from other symptoms, it is thought that "acid-intoxication" is likely to arise as an after-effect, ether should be given in preference to chloroform.

Patients advanced in years generally take anæsthetics better than middle-aged or more vigorous subjects. They are less prone to muscular spasm; they usually require smaller quantities of the drug employed to produce desired effects; and, by reason of the frequency with which their teeth are defective, an oral air-way is readily obtainable for respiratory purposes. Elderly patients are far less liable to after-vomiting than younger subjects. Nitrous oxide may be administered to very elderly people, but care must be exercised. It should not be pushed quite so far as in younger subjects, otherwise, when the inhaler is removed, respiration may not recover itself as quickly as is desirable. The use of oxygen with nitrous oxide

is specially indicated in senile subjects (see p. 306). As a general rule ether should not be given to patients over sixty years of age. The best anæsthetic for routine use in old people is the C.E. mixture, but this should be replaced by chloroform in prolonged operations. Should a senile patient be alcoholic or obese, it is advisable in the course of the C.E. administration to employ ether for a minute or two during the rigid stage.

B. TEMPERAMENT

Patients of a **placid and equable** temperament are, as a rule, easier to anæsthetise than **excitable** and **neurotic** persons. Nitrous oxide is an excellent anæsthetic for patients of the latter class, for by its means excitement—at all events during the administration—may usually be abolished. When longer anæsthesia is required, nitrous oxide may be followed by ether with the best results. Reflex actions are, for the most part, more marked and more difficult to subdue in neurotic and hysterical persons than in those of a non-excitable temperament. As pointed out by Snow, hysterical subjects may display an absence of corneal reflex even though anæsthesia is not fully established. Muscular rigidity is sometimes a troublesome phenomenon in neurotic patients; and, when very sensitive parts are being operated upon or manipulated, there is often a tendency, even during deep anæsthesia, for slight movement or some other reflex effect to manifest itself. Screaming, sobbing, and other emotional disturbances during recovery, are much more common in hysterical and nervous persons than in those of an opposite temperament. In anæsthetising sensitive and fastidious subjects considerable judgment and tact may be needed; in some cases one method will be appreciated, whilst in others another must be adopted. The gradual administration of C.E. or alternate inspirations of nitrous oxide and air may be advantageously resorted to in such cases.

C. HABITS OF LIFE

Patients whose nervous systems have become undermined by alcoholic indulgence, the morphine habit, the excessive use

of tobacco, chloral, or other narcotics, generally display abnormal symptoms during or after anæsthetisation.

The behaviour of **alcoholic subjects** under anæsthetics is generally perfectly characteristic. Considerable quantities of the agent employed may be required to produce the requisite degree of quietude. The author has had to administer $5\frac{1}{2}$ ounces of chloroform, in $1\frac{1}{4}$ hour, to an alcoholic man of fifty-six. It is occasionally difficult, if not impossible, to secure total muscular relaxation in patients of this class, and reflex movements during operations upon sensitive parts may obstinately persist, even though dangerously large quantities of the anæsthetic be administered. In confirmed alcoholics the stage of muscular excitement is usually prolonged, and, at all events with chloroform, there is need for caution during the rigidity and irregular respiration (see p. 409). In certain exceptional cases nitrous oxide seems incapable of producing anything more than an analgesic state. If the gas be given without oxygen, clonic and tonic spasm come about abnormally early and cut short the administration; whilst if oxygen be mixed with nitrous oxide, the anæsthetic element may be insufficient to induce true narcosis. It is in such cases as these that ethyl chloride is often of great service, either *per se* or in succession to nitrous oxide. Alcoholic subjects usually recover quickly and abruptly from anæsthesia, and nausea and vomiting are rare. It is quite a common event for an alcoholic patient who has been anæsthetised for half an hour to regain coherent speech and co-ordinated movement within two or three minutes after the withdrawal of the anæsthetic, even though corneal insensibility and stertor have been present up to the very end of the administration.

The habitual use of **morphine** may render patients comparatively insusceptible to the influence of anæsthetics,[1] although morphia injected shortly before an operation has an opposite effect (see p. 501).

The excessive use of **tobacco** may lead to an irritable

[1] Dr. R. J. Carter has kindly furnished me with details of a case in which the patient, a morphinomaniac, showed extraordinary immunity to the effects of chloroform. An hour and three-quarters were spent in inducing anæsthesia and eight ounces of chloroform were expended.

condition of the pharynx and larynx, and to troublesome coughing during the administration. Hesitating breathing, widely dilated pupils, and tonic or even clonic spasm over most of the body may be met with in great smokers.

Some of the most difficult subjects that the author has had to anæsthetise have been heavy smokers. One man, a patient at the London Hospital, admitted smoking 1 oz. of "plug" tobacco daily. His heart-sounds were very distant and his pulse slow, but no evidence of intrathoracic disease was detected. Ether was given, but it was taken very badly, so chloroform was substituted with little or no improvement. The breathing was much embarrassed, the jaws so rigid that they could hardly be separated by the strongest gag, there was profuse secretion of (?) laryngeal and tracheal mucus, with a moist expiratory râle, and the abdomen was so rigid that the operation could hardly be performed. It was, in fact, with the greatest difficulty that anæsthesia was maintained.

The author has notes of several other cases in which somewhat similar symptoms have arisen. The chief difficulties met with are apparently due to exaggerated spasm of muscles about the floor of the mouth, jaws, and neck. It is quite conceivable that in excessive smokers these muscles may be abnormally developed, and, in consequence of this, inconvenient spasm may arise. Heavy smokers who display great insusceptibility to nitrous oxide may generally be successfully anæsthetised by ethyl chloride administered *per se* or in conjunction with nitrous oxide (p. 495).

Patients who have been **surgically anæsthetised on several previous occasions** may become less and less susceptible to the influence of anæsthetics. A tendency to vomiting at the first few inhalations, swallowing movements, and obstructed breathing, are liable to arise in such cases.

The **ether** or **chloroform habit** is sometimes acquired; but as the amount of anæsthetic inhaled on each occasion is necessarily small, no marked insusceptibility to these drugs may result.[1]

High living, more especially if associated with want of exercise, leads to obesity, plethora, and other conditions, which, as will be presently shown, are capable of modifying the effects of anæsthetics (see p. 161).

[1] An interesting but fatal case of the chloroform habit is recorded by Mr. Percy Court, *Lancet*, vol. ii., 18th July 1903, p. 54.

D. GENERAL PHYSIQUE

The **healthy, vigorous, and stalwart** subject does not pass so easily into anæsthesia as the weaker and more **fragile** patient. This would seem to be principally due to the stage of excitement being more marked, and to muscular spasm, interfering with respiration, being more pronounced than in feeble subjects. The amount of anæsthetic needed to produce narcosis will be found to vary with the general physique of the patient, the total quantity of blood within the vascular system constituting an important factor. For example, a man of six feet in robust health may require from eight to ten gallons, or possibly more, of nitrous oxide, before he is completely anæsthetised; whereas an ill-nourished young woman of short stature may exhibit all the signs of complete anæsthesia from this gas after inhaling from one to two gallons. Emaciated children need remarkably small doses of anæsthetic.

Patients with much **hair about the face**, particularly if they be edentulous, are unsatisfactory subjects for methods of anæsthetisation whose success is dependent upon an accurate coaptation of the face-piece. This is exemplified, to a certain extent, when employing nitrous oxide or ether; but it is exemplified to a much more striking extent when employing nitrous oxide and oxygen or the nitrous oxide-ether sequence. In general surgical practice, indeed, such patients should, as a rule, be anæsthetised with the C.E. mixture or with the C.E.-ether sequence, and not with nitrous oxide and oxygen or with nitrous oxide and ether.

Patients who are the subjects of extreme **obesity** usually exhibit phenomena differing somewhat from those met with in thin and spare individuals. As a general rule they are intolerant of any anæsthetic which, by reason of the method of administration employed, limits the supply of air to any considerable extent. Ethyl chloride is not a satisfactory anæsthetic for such subjects. The C.E. mixture and chloroform are usually better borne than nitrous oxide, ether, or ethyl chloride. There are, however, certain exceptional cases

amongst obese and alcoholic men in which chloroform, when administered to the full surgical degree, produces obstructed respiration, and in these a change to ether must be effected.

Patients with **large abdominal tumours** may be unable to assume the dorsal posture, and it may be necessary to anæsthetise them in the lateral, semi-recumbent, or even the sitting posture (see Illust. Case, No. 16, p. 474). Such patients generally display some degree of respiratory embarrassment during the induction stages, particularly if the dorsal posture be adopted. As in the case of obese subjects, air deprivation should be avoided as much as possible in these cases. A bulky abdominal tumour may not only lead to considerable respiratory embarrassment during anæsthetisation by limiting thoracic and diaphragmatic action, but it may also interfere with circulation. In many cases the circulatory depression which is observed is doubtless dependent upon respiratory embarrassment, but the author is inclined to think that in others it may be due to the simple mechanical pressure of the tumour upon the great abdominal venous trunks. Thus, during the anæsthetisation of a healthy lady for **Cæsarian section**, the patient being in the dorsal posture and moderately deeply under chloroform, it was noticed that up to the point at which the fœtus was removed, the face remained rather pale and the pulse hardly palpable at the radial, temporal, and superior coronary arteries. Immediately, however, the fœtus had been removed the colour markedly improved, and all the arteries mentioned became properly filled with blood. Whether the freer pulmonary circulation or the removal of the pressure from the vena cava and other veins was the chief factor in the improvement it is difficult to say. Probably both factors contributed.

Patients with a **florid colour**, as well as those who are distinctly **plethoric**, require more anæsthetic than anæmic and sallow persons. The parts constituting the boundaries of the upper air-passages may, in vascular subjects, become so engorged as to lessen the capacity of those passages. This vascular turgescence and consequent swelling is most pronounced under nitrous oxide or ether, but may also be observed under other anæsthetics, and appears to be often partly

dependent upon the degree to which air-limitation is practised. The tongue of a plethoric, short-necked patient under nitrous oxide may, for example, become noticeably increased in size. The so-called "falling back of the tongue" is often partly or wholly the outcome of an increased size of that organ. Mucus and saliva are usually freely secreted during the administration of ether to young patients, more especially young women of good colour. When the face of the patient is very florid it will rapidly become dusky or cyanosed, should the air-supply be purposely or accidentally restricted. Thus, under nitrous oxide or ether, red-faced patients assume an appearance which to the onlooker might cause alarm; moderate duskiness of the features is not of itself indicative of any dangerous condition in such cases. As a general rule, florid vascular subjects should be kept deeply anæsthetised; for if only moderate anæsthesia be secured, inconvenient reflex actions will be found liable to result.

Anæmic patients take anæsthetics very well, small quantities being required to secure tranquil anæsthesia. When, however, the anæmia has been induced by loss of blood, as, for example, during the progress of some uterine affection, it may happen that no unusual diminution in the quantity of anæsthetic will be distinguishable. Air-limitation should be practised as little as possible with these subjects, for they are intolerant of any asphyxial state. Nitrous oxide mixed with oxygen is hence a better anæsthetic than the former gas alone. Anæmic subjects have, in fact, a special susceptibility to pure nitrous oxide, so that the effects produced by this gas constitute, so to speak, a test for anæmia. Epileptiform movements coming on very early in a nitrous oxide administration generally indicate anæmia. The most marked illustration of this fact which has come under the author's observation occurred in the case of a lady who was the subject of pernicious anæmia. Epileptiform movements arose after three respirations of pure nitrous oxide, and air had to be then admitted to check the convulsive phenomena. In cachectic and very feeble persons undergoing rather formidable operations it is usually best to secure a fairly deep anæsthesia for the *commencement* of the operation, and then to allow the patient to pass

into a condition of light anæsthesia for the *remainder* of the time.

It is thought by some observers that persons with the **status thymicus or lymphatic constitution** (hyperplasia of the thymus gland, lymphatic glands in general, tonsils and spleen and hypoplasia of heart and aorta) are specially liable to sudden death from cardiac syncope during chloroform narcosis. The evidence in favour of this assumption is not convincing. Patients of this kind, however, are certainly liable to embarrassment of breathing of an obstructive nature, and it is highly probable that the cases of supposed primary heart-failure under anæsthetics have been misinterpreted.[1] Great care is always needed in anæsthetising patients, and particularly children, whose air-way is encroached upon by enlarged tonsils and cervical glands (*vide infra*).

E. THE RESPIRATORY SYSTEM

The State of the Upper Air-Passages. — Certain symptoms during the use of anæsthetics will be found to be dependent upon the manner in which the **teeth** of the lower jaw engage those of the upper. Patients with powerful jaws and irregular and interdigitating teeth, as well as those with perfect teeth which meet accurately, will be liable to exhibit a greater tendency to hampered breathing than patients with feeble jaw muscles and teeth which do not tend to interlock. Moreover, when the upper and lower teeth engage one another in such a manner as to render it difficult to move the lower jaw upon the upper, some embarrassment in breathing may arise. Difficulties are also not uncommon in anæsthetising patients with ill-developed and receding lower jaws. Should the patient be wholly **edentulous** it may be necessary to keep the gums and lips apart, in order to maintain respiration. **Fixity or lessened mobility of the lower jaw**, from disease of its articulations (see Illust. Case, No. 44, p. 538), from local inflammatory conditions, or from the presence in the submaxillary or cervical regions of glandular or other tumours (see Illust.

[1] See a review of the subject by Dr. James Ewing, *New York Med. Journ.*, 10th July 1899, p. 37 *et seq.* See also *Lancet*, 14th November 1903, p. 1386.

Case, No. 45, p. 539), is particularly liable to give rise to asphyxial difficulties.[1] If the nasal air-way be free, breathing will usually take place either partly or wholly through it. If it be more or less obstructed, even by ordinary catarrh, the anæsthetist should insert a small prop between the teeth before the administration of nitrous oxide, nitrous oxide and ether, or ethyl chloride. In patients with complete nasal obstruction special care must be exercised. Mouth-props should be inserted roller-wise (Fig. 69). It must be remembered that although this precaution generally allows of free oral respiration it does not necessarily ensure it, for the tongue may persistently remain in contact with the palate. The presence of a mouth-prop, however, allows of the mouth being quickly opened at any moment should this be necessary.

Patients suffering from **nasal or naso-pharyngeal catarrh** are liable to retch or vomit even during apparently well-established anæsthesia. The author believes this to be owing to the presence within the stomach of swallowed mucus. Similarly, after-vomiting is common in patients, especially children, with naso-pharyngeal affections attended by much mucous secretion. Sometimes the presence of mucus within and above the larynx, as in children with adenoid growths, may bring about an eccentric form of anæsthesia, characterised by stridor, rigidity, curious movements of the arms, hands, and fingers (pp. 81 and 398), and dilatation of pupils. Such phenomena may be met with during the induction stage and may be very disconcerting to the anæsthetist. They appear to be of reflex origin dependent upon the presence of mucus, and though the cornea may be insensitive to touch during their incidence, there may be considerable reflex response if a cutaneous incision be made.

Morbid growths of the tongue, soft palate, tonsils, pharynx, epiglottis, and adjacent parts may, from vascular turgescence or alteration in position, interfere with free respiration during anæsthesia. Any deprivation of oxygen is especially liable to lead to this increase in size. Muscular spasm about the neck and jaws, such, for example, as that which often accompanies the

[1] See an interesting case (*Lancet*, 8th April 1899, p. 959), in which nitrous oxide caused fatal asphyxia.

use of pure nitrous oxide or ethyl chloride, may readily lead to respiratory arrest in these subjects. Both these anæsthetics, indeed, are contra-indicated when any marked narrowing of the upper air-passages is present. Patients with enlarged tonsils will be found to take nitrous oxide with oxygen far better than nitrous oxide administered in the ordinary manner, *i.e.* without any oxygen. With the former system respiration at most becomes snoring; whereas, when nitrous oxide free from oxygen is fully administered to a patient with very large tonsils, embarrassed and obstructed respiration (usually only temporary) will result.[1] But even with non-asphyxial methods, difficulties from enlarged tonsils are likely to occur. Mr. Bellamy Gardner has found the lateral or semi-prone posture advantageous in cases of extreme enlargement. Again, glandular, lipomatous, and other tumours of the neck, including thyroid growths, may, during vascular engorgment, lessen the capacity of the air-way, and thus favour obstructed breathing.[2] Should the patient whose air-way has become narrowed suffer from even occasional or slight difficulty in breathing, the advisability of preliminary tracheotomy should be discussed.

When **dyspnœa from laryngeal disease, narrowing of the trachea, or similar conditions** is present, great care must be exercised.[3] Chloroform is the only admissible anæsthetic in such cases, and the depth of anæsthesia induced should bear an inverse ratio to the degree of obstruction. Patients with slight narrowing of the air-tract generally tolerate the anæsthetic state remarkably well; but when the dyspnœa is considerable, the patient somewhat cyanosed and unable to lie down, and sleep hardly possible, the risks of giving a general anæsthetic are great. The extraordinary muscles of respiration upon which the patient has become dependent are thrown out of action during unconsciousness, the result being that respiration is left to the care of muscles which are in-

[1] Mr. Bailey (*Brit. Med. Journ.*, 29th March 1884, p. 645) reported a case of carcinoma of the tonsils in which respiration ceased (probably in the manner suggested in the text). Tracheotomy became necessary.

[2] See a case, *Lancet*, 1st September 1888, p. 442, and *Brit. Med. Journ.*, 15th September 1888, p. 625. Also *Brit. Med. Journ.*, 29th October 1892, p. 964.

[3] Mr. Bellamy Gardner, in an interesting paper (*Lancet*, 11th June 1898), has discussed the use of anæsthetics in patients with laryngeal paralyses and morbid growths.

capable of overcoming the difficulties present. In this way respiratory arrest may readily arise even though the corneal reflex be brisk. In anæsthetising patients with laryngeal affections, a careful consideration of the precise nature of the disease is essential. In cases of abductor paralysis, for example, it may be necessary to keep the chin forcibly pulled away from the sternum throughout the administration, otherwise dangerous approximation of the lax cords may result. The use of anæsthetics during operations for papilloma of the larynx will be discussed in the following chapter. There are, perhaps, no cases demanding greater care and experience on the part of the anæsthetist than those in which extensive **cellulitis of the submaxillary and cervical regions** is present (**Angina Ludovici**). When this inflammatory state attacks an obese, or thick-necked and muscular man, when the infiltration of the cellular tissues is so extensive that the outline of the lower jaw is lost, and when, as is not uncommon, the patient's habits, as regards alcohol and tobacco, are intemperate, no worse subject for a general anæsthetic exists. If there be no other course than to induce general anæsthesia, the lateral posture should be chosen, a closed Mason's gag introduced between the teeth, the C.E. mixture slowly given to partial anæsthesia, the tongue forceps applied if necessary, and every provision made for immediate laryngotomy or tracheotomy should breathing become seriously embarrassed. Nitrous oxide, ether, and ethyl chloride are all strongly contra-indicated in these cases (see Illust. Case, No. 15, p. 473 and footnote thereto).

Bronchial, Pulmonary, and Pleural Diseases.—So far as the use of anæsthetics is concerned, old-standing lung or pleural affections are of less importance than those more recently acquired. In the former the respiratory mechanism has, by constant use, become adapted to circumstances; whilst in the latter such adaptation is in process of establishment. Patients with **chronic bronchitis, marked emphysema, chronic phthisis, old pleural disease,** and similar conditions take anæsthetics well when care is exercised and the most appropriate agent administered. Speaking generally, ether should be avoided in cases of this group. Its use is not only likely to be attended by strained and difficult expiration with cyanosis,

but to be followed by an aggravation of the respiratory affection. When, however, the respiratory disease is but slight, there is no objection to employing a small quantity of ether (as in the nitrous oxide-ether-chloroform sequence) as a preliminary to chloroform; whilst, as will be explained below, there are certain cases of this group in which the patient's safety is best consulted by securing a light ether anæsthesia during the operation. As a general rule the C.E. mixture or the C.E.-chloroform sequence usually gives the best results in chronic cases. It is hardly necessary to point out that the greater the embarrassment to respiration, the lighter should be the anæsthesia, and the more careful should the administrator be to allow a free supply of air and to prevent all conditions likely to impede breathing. It is a fortunate circumstance that patients with respiratory affections are, as a rule, singularly free from those inconvenient reflex manifestations which generally attend a light form of anæsthesia. Should the bronchial, pulmonary, or pleural affection under which the patient is labouring be of recent origin and of sufficient intensity to cause distress in breathing, much caution must be exercised and a deep anæsthesia avoided. The most hazardous cases are those in which respiratory embarrassment from recent pleurisy or pleuro-pneumonia coexists with quick and hampered cardiac action. When the patient is dusky, his temperature elevated, his breathing rapid, and his pulse accelerated and sharp under the finger, the use of an anæsthetic is attended by considerable risk. This risk is greater in patients with fatty and dilated hearts than in others. Numerous deaths have, in fact, occurred in such subjects from syncope during or immediately after transient struggling.[1] It is in such cases as these, in which the risk is from the cardiac side, that the author finds it best to employ ether although that anæsthetic may appear to be contra-indicated. He therefore uses the C.E.-ether sequence, applying a semi-open ether inhaler *before* the rigid stage and maintaining only a light anæsthesia (see Illust. Case, No. 24,

[1] A typical example will be found in the *Brit. Med. Journ.* i., 1881, p. 385. Ethidene dichloride was being used; the fatal syncope took place when the patient was turned on to his sound side. At the post-mortem the right heart was full and the left empty.

p. 489). Nitrous oxide may be safely used in persons with chronic lung affections, but it should not be pushed quite so far as in healthier subjects. When mixed with oxygen the anæsthesia is of a much more satisfactory nature than when the pure gas is given.

In certain desperate cases in which respiratory embarrassment, with more or less cyanosis, is associated with cardiac disease or with marked depression of the circulation arising from other causes, it may be advisable to administer **oxygen** in conjunction with the anæsthetic, care being taken to introduce this gas to the lungs in such a way as to throw no additional work upon the muscular mechanism of breathing (see Fig. 44, p. 341).[1]

Wholly Thoracic or wholly Abdominal Respiration.—There are various conditions which may give rise to wholly thoracic or wholly abdominal respiration. The former is most frequently met with as the result of peritonitis, or of extreme abdominal distension from intestinal obstruction, ascites, ovarian disease, etc. The latter is most commonly due to advanced emphysema or other affections of the lungs or pleuræ. Should the breathing be wholly thoracic[2] or wholly abdominal, the administrator will, of course, meet with more exaggerated respiratory movement than usual. If a patient, from some acute condition, be obliged to use his thorax or abdomen only, and if the new form of respiration be somewhat difficult for him to acquire by reason of pre-existing conditions, such as emphysema or obesity, anæsthetics must be used with great caution. When the **abdomen** is **greatly distended** from ascitic fluid, a light anæsthesia only is necessary during its removal (see Illust. Case, No. 16, p. 474), and the administrator will find that both respiration and circulation will markedly improve as the fluid is evacuated and the lungs become able to expand more freely. Reference has already been made (p. 162) to the anæsthetisation of patients with large abdominal tumours.

[1] The arrangement of apparatus in Fig. 44 is quite as applicable for the C.E. mixture and oxygen as for ether and oxygen.

[2] In a case reported by the author in the *Lancet*, 19th March 1896, p. 772, the diaphragmatic paralysis which was present was probably due to peripheral neuritis (see Illust. Case, No. 9, p. 363).

Morbid States of the Central Nervous Mechanism.— For remarks on this subject see pp. 175 and 176.

F. THE CIRCULATORY SYSTEM

Of the numerous misconceptions which still exist concerning the effects of anæsthetics, that of gauging the risk of anæsthesia by the state of the patient's circulation is perhaps the most conspicuous. It is often erroneously supposed that the possession of a vigorous vascular system affords a guarantee of safety, whilst the existence of organic cardiac disease or of a so-called weak heart almost contra-indicates surgical anæsthesia. As a matter of fact, a precisely opposite view would more nearly approach the truth. With the most vigorous type of circulation there is usually associated a vigorous physique, and, as we have already seen, powerfully built subjects are often difficult to anæsthetise, and not unfrequently give considerable trouble or even anxiety to the anæsthetist. On the other hand, patients with organic or functional circulatory derangements usually possess comparatively feeble muscular systems and pass into deep anæsthesia with little or no excitement or difficulty. At the same time, there are of course many cases in which, by reason of the state of the circulation, special lines of treatment are indicated, and unless such lines be followed, serious consequences directly dependent upon the cardio-vascular conditions may result. Other things being equal, the more vigorous and adaptable the circulation, the better will it be able to withstand any strain, asphyxial or otherwise, to which it may be subjected during anæsthesia.

The circulation may be of the most efficient type; or it may be so feeble as to render it questionable whether any operation should be performed. The pulse may be so rapid that it can hardly be counted, or it may be abnormally slow.

Abnormally **rapid cardiac action (tachycardia)** is most frequently due to nervousness. When this is the cause of the quickening a considerable slowing will invariably occur during anæsthesia; but when the rapid pulse is due to shock or exhaustion, an increase in rate will usually take place (see

Illust. Case, No. 70, p. 586). In a patient with Graves's disease to whom I administered chloroform after ether, the tachycardia was practically unaffected during anæsthesia, the pulse rate during an operation lasting an hour and a half being about 180 per minute.

Patients with an **abnormally slow pulse (bradycardia)**, especially middle-aged and elderly persons, may display, during deep chloroform anæsthesia, a somewhat disconcerting degree of circulatory depression together with halting Cheyne-Stokes, or even arrested breathing (see p. 561).

Valvular and other Cardiac Affections.—Patients with these affections may be anæsthetised with safety if care be taken to select the anæsthetic most appropriate to the case, and to administer it in such a manner that no undue strain is thrown upon the heart. When the cardiac affection is but slight, and, by reason of compensatory changes, the general circulation is good, little or no alteration need be made in the anæsthetist's usual practice. There are one or two points, however, which should be borne in mind in dealing with **advanced cases.** Unless orthopnœa exist, the recumbent posture should be enforced; no marked or prolonged deprivation of oxygen permitted; and any interference with respiratory rhythm prevented. The anæsthesia of nitrous oxide followed by ether is not to be recommended in these cases. A well-marked instance of the ill effect of employing a "close" and asphyxiating method of administration in a patient with mitral obstruction and aortic regurgitation occurred at the London Hospital in 1897; cardiac rapidity and irregularity, with dusky pallor of the face and failing pulse, were observed after a short inhalation of ether by means of Clover's inhaler. Dr. Guthrie records the case of a fat baby, five months old, with congenital pulmonary stenosis, in whom chloroform caused early cessation of breathing, with cyanosis, and finally pallor. All methods should be gradually conducted, and the slightest respiratory embarrassment assiduously avoided. Speaking generally, the C.E. mixture is an excellent anæsthetic for patients with advanced morbus cordis (see Illust. Cases, Nos. 18, 19, and 20, p. 475). Ether (preceded by a small quantity of the C.E. mixture to prevent its disagreeable odour) may be

used in eases in which **orthopnœa** is present, and only a short unconsciousness is required. By the gradual administration of the C.E. mixture to a patient with an intermittent or irregular pulse, the heart's aetion generally becomes steadier, and remains so for a considerable time. The anæsthetist must not, however, shut his eyes to the faet that after the withdrawal of the anæsthetie, or during a serious operation, this improvement may, and often does beeome replaeed by irregularity and feebleness in exeess of the original eondition.

The remarks here made with regard to valvular eardiae affections apply with equal foree to cases in which **fatty or other degenerative changes** are present in the myocardium. Provided that the respiration be kept free from embarrassment and that a very deep anæsthesia be avoided, the "fatty heart" is not injuriously affeeted by anæstheties. Any asphyxial strain, however, may quickly impair its aetion and lead to syncope (p. 415). Moreover, surgieal shoek is more likely to assume grave proportions in eases of advaneed eardiac degeneration than in others.

For patients with **pericarditis**, who are very ill, with quiek feeble pulse, the C.E. mixture given to moderate anæsthesia only, answers well. The pulse may be observed to improve when a distended pericardium is incised and the fluid removed.

Atheroma.—In extremely atheromatous subjects there is a slight risk [1] of eerebral hæmorrhage during anæsthesia. This risk may, however, be minimised by seleeting the C.E. mixture or ehloroform in preference to ether; and by avoiding, as far as possible, exeitement, holding of breath, coughing, and struggling during the administration. In patients who have previously suffered from cerebral hæmorrhage ether is strongly eontra-indieated [2] (see p. 367).

Should arterial degeneration have led to the formation of

[1] See a ease which oecurred in the praetiee of Dr. Fuller of Montreal, reported in *Canadian Med. and Surg. Journ.*, March 1888, p. 309, and referred to in Dr. Turnbull's 3rd edition of *Artificial Anæsthesia*, p. 252.

[2] Some years ago a case oecurred at the London Hospital, in which a patient, a man of sixty-two, died from eerebral hæmorrhage, which apparently took place whilst he was under the influenee of ether. The operation, which was a short one, was for the removal of a growth of the breast. Clover's inhaler was used, and there was but little struggling. The patient never became thoroughly conscious after the operation; and hemiplegia was found to be present. Death oecurred in a few days.

an **aneurysm**, the same caution as to the avoidance of struggling, straining, coughing, etc., must be exercised. It is true that ether has very frequently been given to patients with large aneurysms without rupture having occurred; but when there is any evidence of rapid increase in size, and more particularly when the aneurysm is intrathoracic, the C.E. mixture or chloroform should be used in preference to ether.

Venous Thrombosis.—Patients with venous thrombosis must be carefully treated. They should be moved as little as possible, and special precautions should be taken to avoid struggling and excitement. An interesting case, in which fatal syncope arose under ether in consequence of a clot from the common iliac vein becoming dislodged and entangled in the tricuspid orifice, is given on p. 568. An almost identical case is reported [1] from abroad, the patient, who was suffering from long-standing suppuration, having died during the first few inhalations of chloroform. It is by no means improbable that some of the sudden deaths which have occurred under anæsthetics, and which have been ascribed to their action, have in reality arisen from cardiac or pulmonary embolism.

Exhaustion: Shock: Collapse.—One is often called upon, more particularly in hospital practice, to anæsthetise patients whose circulation has become much enfeebled, either from some long-standing disease or from some recently acquired but prostrating malady. As illustrations may be mentioned—cases of hip disease and hectic in children, cases of advanced stricture of the pylorus, cases of strangulated hernia, and cases of collapse from railway or other injuries. Such patients are very susceptible to anæsthetics, small quantities only being necessary to induce and maintain anæsthesia. As a general rule, the pulse of the exhausted patient improves in volume when anæsthesia is established; but, when the anæsthetic is withdrawn, some depression of the circulation may follow. Moreover, this initial improvement does not, as a rule, last long; and any loss of blood, prolonged exposure, or severe surgical procedure will soon give rise to signs of circulatory depression. The administrator must do all in his power to sustain the strength of his patient. If the heart's

[1] *Brit. Med. Journ.*, 31st March 1906 (p. 46 of epitome).

action be very feeble, no method of administration should be employed by which the supply of air is greatly restricted, and all mechanical or other hindrances to free respiration must be avoided. Ether is, as a rule, best administered by the semi-open method and in small quantities at a time. If a close inhaler be used, care must be taken to remove it frequently for the admission of air. The administration of nitrous oxide is best avoided in these cases. Exhausted and collapsed subjects are liable to display a peculiar state of the eyes during anæsthesia, and more particularly during deep anæsthesia, the lids failing to close and the globes turning upwards so that the sclerotics only are visible. Profuse sweating is also common in these subjects, and is another indication of exhaustion. The administrator must be on his guard with reference to the rosy cheeks of **hectic subjects** and of those artifically stimulated by alcohol or opium. This florid colour may coexist with a circulation totally unable to withstand any very prolonged surgical interference (see Illust. Case, No. 70, p. 586).

Cases of **intestinal obstruction** are, perhaps, appropriately referred to under this heading, seeing that syncope of the worst type may occur during anæsthesia. The abdomen is usually distended, and the diaphragm unable to act efficiently; the stomach frequently contains fluid or semi-fluid material; the patient is, in many instances, partly under the influence of an opiate; and the circulation, though often artificially stimulated by alcohol, may be unable to withstand any strain. When vomiting is frequent, the abdomen distended and inactive, the pulse quick and feeble, the extremities clammy and dusky, the features pinched and the lids half open, general anæsthesia may be extremely hazardous. In less advanced cases an anæsthetic may generally be safely given. For further remarks the reader is referred to pp. 206 and 213, and to Illust. Cases, No. 17 (p. 474) and No. 27 (p. 504).

Acetonæmia: Acetonuria: "Acid Intoxication."—Although these conditions are principally of interest in their relation to the after-condition of the patient, recent observations tend to show that they are also of interest in their relation to the state of the patient before anæsthesia. For

remarks on these allied conditions the reader is referred to pp. 157, 177, 231, and 604.

G. THE NERVOUS SYSTEM

Should the patient be **drowsy** or **half-conscious** at the time of operation, very small quantities of the anæsthetic will be needed. When well-established **coma** is present, the services of an anæsthetist will not, of course, be required. The subjects of **depressed fracture of the skull, intracranial hæmorrhage, cerebral abscess, or cerebral tumour** may, at the time of operation, be so lethargic that a few inhalations of the anæsthetic will readily produce the quietude desired. It must be remembered that patients with cerebral or cerebellar tumours may, apart from the use of anæsthetics, display symptoms of primary respiratory failure from increased intracranial tension; and when any tendency in this direction exists, the induction of even light anæsthesia may completely suspend breathing.[1] The employment of morphine prior to cerebral operations will be specially discussed hereafter (see p. 502).

Patients whose perceptive faculties have become blunted by the absorption of poisonous products during the course of intestinal, vesical, renal, or similar affections, often pass into anæsthesia with a marked absence of excitement and rigidity; and display a florid colour and good pulse throughout the administration, provided that the corneal reflex be not completely abolished. Very deep anæsthesia is unnecessary in such cases. The author has often been struck by the fact that patients of this kind behave in much the same way as if a preliminary injection of morphine had been given.

Patients who are the subjects of chronic nervous affections may exhibit peculiar respiratory phenomena during anæsthesia. Thus, the author has notes of two cases—one patient had **disseminated sclerosis**, and the other advanced **tabes dorsalis**—in which, during the use of an anæsthetic (ether), breathing was jerky, catchy, halting, and split up, as it were, by long pauses. In the ataxic patient some degree of laryngeal

[1] The author has related a case of this kind (*Practitioner*, 1887, vol. xxxix. p. 93), and Dr. E. F. Fison of Salisbury (*Lancet*, 4th August, 1900, p. 329) records another. In both artificial respiration was maintained for four hours.

obstruction, with prolonged expirations, was noted, and caused some trouble.[1]

The subjects of **epilepsy** may be safely anæsthetised. In some cases a more or less distinct attack occurs during the exhibition of the anæsthetic. The author has, on one or two occasions, noticed in these subjects a greater tendency than usual to tonic and clonic spasm during the administration of nitrous oxide.[2] In only one case has the author known a distinct and characteristic epileptic seizure to arise, and in this the attack began after a few breaths of the gas, *i.e.* before the occurrence of the usual asphyxial phenomena.

The administration of anæsthetics to patients with a history of previous **insanity** is liable to be followed by a fresh attack. According to Dr. Savage,[3] patients subject to recurrent seizures of mental disorder are particularly liable to be thus affected. There is, apparently, no special objection to anæsthetising patients already insane, except, of course, in the case of maniacal subjects. The author has met with one or two cases of exaggerated excitement in patients with a family history of insanity.

Lastly, cases occasionally, though rarely, present themselves, in which, owing to **some peculiarities in the nervous system**, of whose nature we are ignorant, the induction and recovery period are characterised by violent struggling or maniacal excitement. The author has on more than one occasion met with these eccentric states in members of the same family. Certain patients behave as if they had drunk freely, although no evidence can be obtained of alcoholism. The so-called "neurotic" subjects, and those whose nervous systems are peculiarly unstable or hypersensitive, seem to be most liable to these uncontrollable outbreaks. The treatment most likely to be successful in such cases is the administration, some hours before the anæsthetic, of sedatives, such as potassium bromide and chloral (see Illust. Case, No. 35, p. 516).

[1] A similar case is recorded by Dr. Lamb (*Lancet*, 16th May 1903).

[2] Mr. Woodhouse Braine believes (*Med. Soc. Proc.*, vol. viii. 1885, p. 64) that there is greater risk of an epileptic attack being brought about by tooth extraction without an anæsthetic than when one is used.

[3] See an interesting and important paper by Dr. G. H. Savage—"The Relationship between the Use of Anæsthetics and Insanity (*Lancet*, 11th November 1899).

H. RENAL DISEASE

Opinions are still divided as to the choice of anæsthetics in patients suffering from renal disease. The fact that very contradictory results have been arrived at by observers who have investigated the relative influences of ether and chloroform upon the urinary functions would seem to indicate that there is not that objection to the use of ether that was formerly held to exist. At the same time, it is obviously important, when anæsthetising patients with advanced forms of kidney disease, to avoid prolonged etherisation, and to employ methods which will throw as little strain as possible upon the circulatory and respiratory functions. The liability of such patients to respiratory complications should be specially borne in mind. For further remarks see pp. 366 and 425.

I. DIABETES MELLITUS

The presence of diabetes in a patient about to be anæsthetised must always be regarded with some degree of anxiety. Numerous cases, indeed, have been recorded in which fatal **diabetic coma** has apparently been initiated by anæsthetisation. Unfortunately our knowledge as to the rôle played by the anæsthetic in such cases is very inadequate. Some observers believe that the presence of **acetone** in the urine of a diabetic patient renders that patient particularly liable to fatal coma. This view has been urged by Becker,[1] who has reported three fatalities after anæsthesia in patients whose urine contained acetone at the time of operation. Becker also found records of twelve other fatalities after anæsthesia in diabetic subjects. Gerhardt and others state that the urine and blood of diabetics frequently contain, in addition to acetone, both diacetic acid and β-oxybutyric acid. If the administration of ether or chloroform occasionally brings about, as some observers maintain, a state of acid-intoxication

[1] For these references to Becker and Gerhardt I am indebted to Dr. J. A. Kelly, of New York. See *Annals of Surgery*, February 1905, p. 171, "Acid Intoxication: its Significance in Surgical Conditions."

characterised by the presence of these three substances within the blood (p. 604), it is quite conceivable that the administration of an anæsthetic to a diabetic patient whose blood already contains these bodies may induce fatal coma. Further research, however, is needed before any more definite pronouncement can be made upon this interesting subject. There would seem to be a distinct connection between the condition of "acid-intoxication" or "delayed chloroform poisoning" and the coma which is liable to follow the administration of an anæsthetic to a diabetic subject.

Dr. Pavy, whose contributions to the subject of diabetes are so well known, has very kindly furnished me with his views as to the influence of anæsthetics upon patients suffering from this affection. In cases "under control," in which sugar is at the time either absent from the urine or present only to a slight extent, he thinks that general anæsthesia is unattended by risk. But when the quantity of sugar in transit through the system is abnormally large, any profound disturbance of the vital processes, such as that attendant upon the use of an anæsthetic, especially for a protracted operation, may upset the balance, and lead to fatal diabetic coma.

With the above considerations before us it is clear that in the event of a diabetic patient requiring a surgical operation—(1) special attention should be paid to the diet for some time before the administration, with the object of reducing the quantity of sugar in the circulation; (2) free purgation and skin action should be obtained before anæsthetisation; (3) the anæsthetic should be very carefully chosen in order that the general after-effects may be reduced as far as possible; and (4) the anæsthesia should be as short as is compatible with the needs of the surgeon, and no more of the anæsthetic given than is necessary for the particular operation in hand. According to recent observations, the presence of diacetic acid in the urine would seem to indicate a course of alkalies before anæsthetisation, and the selection of ether in preference to chloroform.

Although the author has not himself met with a case of diabetic coma after anæsthesia, he has been given brief notes of such a case by one of our leading surgeons. The patient

suffered from diabetic boils, several of which had been incised without the employment of an anæsthetic. At 9.30 one morning, ether, preceded by nitrous oxide, was administered for further incisions; but the patient never recovered consciousness, and died at 4 P.M. the same day.[1]

J. MENSTRUATION. PREGNANCY. LACTATION

Opinions are still divided as to the advisability of performing operations during the **menstrual period.** In cases of any urgency the question will not, of course, arise. In other cases the anæsthetist is often consulted as to the propriety of giving an anæsthetic. Speaking generally, it may be said that if the case be not urgent it is better to postpone the administration and operation. In some patients the nervous system is distinctly unstable at the menstrual periods, so that even a slight operation under a general anæsthetic may be accompanied or followed by unusual symptoms. Moreover, it is not an uncommon event for hysterical and other patients to erroneously ascribe a multitude of unusual after-effects to the circumstance that the anæsthetic was given during menstruation. Hæmorrhage after tooth extraction is said to be greater during menstruation than at other times; but this is doubtful. The author once observed very considerable hæmorrhage during and immediately after a nasal operation in a young woman in whom menstruation had been proceeding for forty-eight hours previously.

If an operation has to be performed during **pregnancy,** an anæsthetic may unhesitatingly be given. No departure from ordinary rules is necessary during the earlier months. The diet should be cautiously regulated in order to avoid retching or vomiting after the administration. Nitrous oxide may be given with safety till the sixth or seventh month; but after that time it is probably better not to administer this anæsthetic, or, at all events, not to administer it in such a manner as to excite clonic muscular movements. The author has given nitrous oxide and oxygen to a patient about thirty-five years of age who was within seven to ten days of her confinement. She

[1] See also Kauch, *Centralblatt für Chirurgie*, No. 27.

experienced no after-effects of any kind from the anæsthetic. Laffont, quoted by Dr. Buxton, refers to a case of a female aged thirty-seven who was eighteen weeks pregnant when nitrous oxide was administered to her. Abortion followed, which he believed to be due to the gas having produced some asphyxial changes in the blood.[1] Chloroform, as is well known, is taken comfortably by pregnant women, when the pains of labour have to be relieved (see p. 219). In the event of a surgical operation being required during the latter months of pregnancy, the safety of the patient will probably best be consulted by using the C.E.-ether sequence or the C.E. mixture throughout. Should ether produce respiratory difficulty, cough, etc., it should not be persisted in; but the mixture or chloroform substituted.

The use of anæsthetics during **lactation** in no way interferes with that process.[2]

[1] *Brit. Journ. of Dent. Science*, 15th October 1898, 917.
[2] *Med. Chir. Trans.*, vol. xlvii. 1864, p. 435.

CHAPTER VII

THE SELECTION OF ANÆSTHETICS, SEQUENCES, AND METHODS IN PARTICULAR AND EXCEPTIONAL CASES (*continued*)

PART II.—THE SURGICAL OPERATION OR PROCEDURE AS A FACTOR

ALTHOUGH the selection of the anæsthetic should be chiefly regulated by the general state of the patient, the nature of the operation, procedure, or condition for which anæsthesia is to be induced should be carefully taken into consideration. There are, for example, certain operations which should unquestionably be performed under certain anæsthetics. Again, there is a tendency during some surgical procedures for circulation or respiration to become injuriously affected, and, unless the administrator be aware of such contingencies, he may erroneously attribute the phenomena to the action of the anæsthetic. Lastly, when certain parts of the body are being manipulated or operated upon, there is need for a somewhat deeper or lighter anæsthesia, as the case may be, than is requisite under other circumstances.

A. OPERATIONS WITHIN OR ABOUT THE MOUTH, NOSE, PHARYNX, AND LARYNX (EXCLUDING THE EXTRACTION OF TEETH, SEPARATELY CONSIDERED)

The procedures of the surgeon and those of the anæsthetist are so intimately associated in this branch of surgery that a clear mutual understanding, coupled with a feeling of "give-and-take," should always exist before the administration commences. It is highly probable that many a fatality has

arisen in connection with operations of this group, from the association for the first time of surgeons and anæsthetists totally unfamiliar with one another's principles and methods. On the one hand, the anæsthetist should ascertain the precise nature and probable duration of the operation; the order in which its different stages will be performed; the requirements of the surgeon as regards the avoidance of hæmorrhage, depth of anæsthesia, etc.; and the posture in which the operator wishes his patient to be placed. On the other hand, the surgeon should know the capabilities of the anæsthetist and the lines upon which the latter proposes to secure the anæsthesia required; whilst he should also endeavour, so far as may be possible, to meet any special views of the practitioner in charge of the anæsthetic as to the posture, depth of anæsthesia, etc., which, in the particular case, would give the best results.

It is in cases of this group that the administrator of the anæsthetic should be particularly careful as to the cleanliness of the apparatus he employs and the sterilisation of his gags, mouth-tubes, etc. (p. 260).

Operations upon the Lips, Cheeks, Jaws, Tongue, Floor of the Mouth, Palate, Tonsils, Naso-pharynx, and Nose.—With our present methods it is possible to safely and satisfactorily anæsthetise all patients requiring these operations, provided attention be paid to certain important details which may now be conveniently considered.

(1) **Selection of Anæsthetic; Depth of Anæsthesia.**—For operations not exceeding 30 to 40 seconds, nitrous oxide (p. 267), nitrous oxide and air (p. 294), or nitrous oxide and oxygen (p. 306) will answer well. For those of from 30 to 90 seconds an administration of ethyl chloride (p. 436), the C.E. mixture (p. 463), or nitrous oxide, followed by a small quantity of ether (p. 481), according to the type of subject and other circumstances, will meet the case. When a total available unconsciousness of from a minute and a half to three minutes is required, two courses are open to the anæsthetist. He may either employ the nitrous oxide-ether, the C.E.-ether, or the ethyl chloride-ether sequence (pp. 479, 484, and 487), pushing the administration of the last-named anæsthetic till it is judged that a sufficient

after-anæsthesia will result; or he may proceed as he would in a more lengthy case, using the nitrous oxide-ether-chloroform, the C.E.-ether-chloroform, the ethyl chloride-ether-chloroform, or the C.E.-chloroform sequence. The former plan has the undoubted disadvantage of favouring inconvenient hæmorrhage, and if it be adopted, special attention must be paid to posture (*vide infra*). In the latter plan a comparatively small quantity of ether passes through the circulation, and, as a general rule, the operation is not attended by undue hæmorrhage. When a continuous and protracted anæsthesia is desired, one of the four sequences just mentioned should be chosen, chloroform anæsthesia being maintained till the termination of the operation. The late Mr. J. Mills[1] was, the author believes, the first to use Junker's inhaler (p. 367) for maintaining chloroform anæsthesia in these cases. Before changing from ether to chloroform, the anæsthetist should ascertain whether respiration is taking place through the mouth or nose. It is obviously next to useless to insert the tube of Junker's apparatus into, or place a mask sprinkled with chloroform over, the mouth, when respiration is taking place through the nose. Generally speaking, it is best to pass a flexible rubber catheter of fairly large bore through the anterior nares so that its free end may be felt just beyond the soft palate. It is easier to maintain anæsthesia by this means than by the use of a mouth tube. Very often, however, a nasal tube is inadmissible, and a mouth tube must be used, under which circumstances the anæsthetist must be careful to see that respiration is oral, and if necessary the anterior nares should be plugged with lint.

Patients requiring these operations may either be suffering from respiratory embarrassment or may be in such a condition that respiratory embarrassment will almost certainly arise during the induction period. The selection of anæsthetics in such cases has already been fully discussed (p. 164).

With regard to the depth of anæsthesia which is advisable, this must depend, to a certain extent, upon the patient's general condition, the posture, and the exigencies of the particular

[1] *Lancet*, 14th December 1878, p. 839. Mr. Mills found, and the author can corroborate his statement, that it is not always easy to keep up anæsthesia by this means in alcoholic subjects.

operation. Provided the general condition be satisfactory and the air-passages not seriously obstructed, a fairly deep anæsthesia may be secured at the outset, in order to allow of the proper adjustment of the gag, etc. When once the operation has been begun it is usually advisable to attempt to retain swallowing and coughing movements without the occurrence of body movements. A deeper anæsthesia than usual may be permitted when the posture is one in which blood cannot enter the larynx. Speaking generally, the greater the hæmorrhage the lighter should be the anæsthesia. In those operations in which coughing or other indications of moderate anæsthesia might be detrimental to the surgeon, *e.g.* cleft palate and intra-laryngeal operations, deep anæsthesia will be essential.

When the actual or the galvano-cautery has to be used, ether and ethyl chloride must be avoided owing to the inflammable character of their respective vapours. There is, however, no objection to placing the patient under ether and then changing to chloroform, but the cautery should not be used till two or three minutes after the change. Deep anæsthesia is needed in order to ensure perfect quietude.

(2) **Posture ; Avoidance of Blood entering the Larynx and Trachea.**—A smooth and successful anæsthesia can only be secured in cases of this group by careful attention to the posture of the patient. In addition to the remarks commencing on p. 237, there are certain special considerations which apply to mouth, nose, and throat operations. The following are the postures in which these operations may be and are performed :—

(i.) *The dorsal, with the head neither flexed nor extended ;*

(ii.) *The dorsal, with the head completely extended over the end of the table or couch ;*

(iii.) *The dorsal, with the head turned to one side ;*

(iv.) *The dorso-lateral, with one shoulder raised, and with the head turned to the opposite side ;*

(v.) *The purely lateral ;*

(vi.) *The latero-prone, with the face pointing downwards towards the floor ;*

(vii.) *The semi-recumbent or "propped-up" posture, with the head in the body axis,* i.e. *neither flexed nor extended ;*

(viii.) *The semi-recumbent or "propped-up" posture, with the head extended over the pillow ;*

(ix.) *The sitting ;*

(x.) *The "bent-forwards" ; and*

(xi.) *Trendelenburg's posture.*

Most of these are figured in Chap. VIII. (p. 238). If posture (i.) be adopted, care must be taken to have at hand several small coarse sponges, unattached to holders, for keeping the fauces free from blood; the anæsthesia should not be profound; and if the hæmorrhage be excessive, the head must be frequently turned to one side. For the last fifteen or sixteen years the author has anæsthetised patients thus placed for a well-known throat surgeon and has had no case of anxiety. Posture (ii.), in the author's experience and opinion, should be proscribed in throat operations. It renders swallowing and coughing difficult or impossible, so that the larynx may readily be invaded; it increases hæmorrhage by retarding the flow of venous blood from the head; and if the nasal channels be blocked, it does not always provide that free drainage for blood which is the avowed object of the posture. Posture (iii.) is not so satisfactory as posture (v.). Seeing that in each case the head is on the side, there is no advantage in the body being supine. In other words, if the operator can operate with the head on the side, the trunk should be placed upon the side also. Some surgeons favour the fourth posture, especially for cases in which it is important that a good view of the palate, tongue, or fauces should be obtained, and it is certainly very useful when the purely lateral posture would be inconvenient. Of all postures, however, the lateral is undoubtedly the best so far as the anæsthetist is concerned. The patient should be placed strictly upon his side, with his legs flexed and with one cheek resting on the pillow, the open mouth being turned so that it directly faces a window. Owing to the facility with which all blood flows out of the mouth, sponging is generally unnecessary: and it is possible to keep up a deep and uninterrupted anæsthesia throughout by means of Junker's inhaler. The next posture (vi.) is usually inconvenient to the surgeon, and has no advantage

over the purely lateral. Of the two semi-recumbent or "propped-up" postures (vii. and viii.) that in which the head is not extended is the better, but both are open to objection from the anæsthetist's point of view, for when patients are thus placed, all blood must, of necessity, drain backwards, and turning the head to one side does not permit the blood to escape as it would if the patient were flat. So far as the surgeon is concerned, posture (viii.) is an admirable one in tongue, jaw, and other cases; but it is practically impossible for the anæsthetist, however skilled he may be, to maintain that unembarrassed form of anæsthesia which may be depended upon in other postures. With regard to (ix.), the sitting posture, there can be no doubt that for many rhinological and other operations of this group it is, from the operator's standpoint, exceedingly convenient. There is certainly no special risk of administering nitrous oxide, ether or ethyl chloride to sitting patients, but the question arises, Are we justified in employing chloroform? The author believes that the proper answer to this question is to be found in the following considerations, viz.: (1) that it is certainly unwise for any one to administer chloroform *ab initio* to patients thus placed (p. 129), although there are certain exceptional cases in which this plan must be followed;[1] (2) that unless the administrator has had a large experience in giving anæsthetics, it is not advisable for him to give any other anæsthetic than nitrous oxide, ether, or ethyl chloride to sitting patients; but (3) that provided the anæsthetist be thoroughly experienced, there is no objection to his first placing a sitting patient well under ether in the manner already described (p. 183) and continuing the anæsthesia by means of chloroform. In conducting such cases he should keep the patient's head, as far as possible, in a line with the body; maintaining only moderately deep anæsthesia, *i.e.* not completely abolishing the corneal reflex, and sponging out the fauces with small coarse sponges from time to time. For these operations a comfortable arm-chair with a slightly sloping back is essential, and it is well to have at hand two or three sofa cushions, or folded bath towels as pillows, in order to obtain the proper head adjustment. As satisfactory anæsthesia becomes

[1] As in operating for laryngeal growths in children. See p. 196.

established it will be found that the relation of the head to the trunk alters, so that an extra pillow behind the head will be necessary in order to bring the latter into the body line. Great care will be required in anæsthetising patients with a comparatively insensitive larynx. Coughing and swallowing are the two safeguards in these cases; and if, as sometimes happens, one has to anæsthetise a patient who does not clear the larynx by cough, even though quite lightly anæsthetised, repeated sponging must be relied upon. Although the author has anæsthetised a large number of patients in the sitting posture for throat and nose operations, he has only been obliged to place the patient horizontally on two occasions. In neither case, however, was this necessary by reason of any circulatory phenomena. The patients were thick-necked, heavily built, fat, florid, and bronchitic men with narrow air passages and sensitive nervous systems, and it was difficult or impossible to keep respiration unembarrassed and the air-way free during operations involving the nose and throat. Both patients were successfully anæsthetised in the dorsal or dorso-lateral posture. The "bent-forwards" posture (x.) may be employed when the natural or artificial nail is used for removing post-nasal vegetations. The patient is first placed under ether in the dorsal or sitting posture, and bent forwards during the scraping process. Sir William Dalby [1] advocates this position, and it certainly has the merit of preventing blood from embarrassing respiration; but as this can be equally well accomplished in the side posture, the latter is generally preferred by surgeons. The last posture (xi.) to be considered is that known as Trendelenburg's. Its advantage in these cases is that it provides for the flow of blood away from the larynx, but it has the drawback that it undoubtedly favours hæmorrhage. It is, however, useful in hare-lip cases in children; and some surgeons speak well of it for cleft-palate operations.[2] It is inadmissible when the patient is even slightly dyspnœic beforehand, or when the manipulations of the surgeon necessarily involve some degree of dyspnœa during the administration; for in a patient thus placed,

[1] "Adenoid Growths in the Pharynx," *Lancet*, Oct. 1886, p. 618.
[2] Keen of Philadelphia advises this posture for operations upon the naso-pharynx (*Annals of Surgery*, 1897, p. 97).

any intercurrent asphyxia is liable to become intensified. The author has seen one or two remarkable examples of this faulty practice, the patient's face and scalp becoming œdematous from the accumulation of blood in the venous system, whilst his radial pulse has become gradually imperceptible as the result of the pulmonary stasis.

The entry of blood into the larynx and trachea during these operations may be easily avoided by attention to the following simple rules:—(*a*) When practicable, the posture should be such that blood can easily flow out of the mouth; (*b*) the head should be kept, as far as possible, in a line with the body, so that coughing and swallowing movements may effectually take place; (*c*) the anæsthesia should not be profound, otherwise the pharyngeal and laryngeal reflexes will be abolished; and (*d*) the anæsthetist should have at hand several small, round coarse sponges unattached to holders, so that, in the event of it being impracticable to adopt a posture favourable for the escape of blood, this fluid may be repeatedly removed by sponging. The cases in which asphyxial complications from blood are most to be feared are those in which the larynx has become, during the course of chronic throat or nose disease, comparatively insensitive. In such cases coughing and swallowing may not take place even during a light anæsthesia, and if the posture be faulty, a fine, moist, expiratory râle will become audible, indicating that blood is present in the larynx, trachea, or large bronchi. The treatment of this condition is considered on p. 540. For operations in the dorsal, the semi-recumbent, and the sitting postures, a widely-opening Mason's gag (Fig. 14, p. 256) generally answers well enough; and one fitted with tubes for transmitting chloroform vapour (Fig. 50, p. 380) may be employed if desired. When, however, the lateral or latero-prone posture is employed, a Mason's gag may be out of the question, and it is best under these circumstances to insert a dental mouth-prop (Fig. 19, p. 258) between the teeth or gums of the side next the pillow; to employ the long screw-gag shown in Fig. 52, p. 381; or the little appliance of Fig. 53, p. 381. Difficulty may often be experienced in maintaining breathing with the mouth widely open, for the tongue may be thus thrown against the pharyngeal wall. By forcing the chin

away from the sternum and relaxing the gag slightly, such difficulties usually disappear. A very small Mason's gag is essential for children, and generally answers better than any other for operations upon the palate. After operations of this group the gag should be relaxed (but not removed till distinct signs of recovery occur), and the patient placed in the lateral posture.

(3) **The Exigences of the Particular Operation.**—In operations upon the **lips** and **cheeks** the lateral or dorso-lateral posture will give the best results. The "propped-up" position, with the head extended, is likely to lead to difficulties. For **hare-lip** operations the infant's body should either be placed in Trendelenburg's posture or it should be semi-inverted by means of pillows, chloroform anæsthesia being kept up either by pumping the vapour through the tube of a Junker's inhaler held several inches away from the mouth, or by a Skinner's mask or lint held horizontally above the site of operation. It is well to keep a finger upon the radial pulse in these cases, unless other indications are present as to the depth of anæsthesia.

For operations upon the **jaws** the lateral or dorso-lateral posture is again to be recommended. The author has on more than one occasion known the superior maxilla to be removed from a patient lying upon the side without it being once necessary to sponge out the fauces. Operations upon **the antrum** are certainly conveniently performed with the patient lying upon his non-affected side in the strictly lateral posture, facing a good light. The mouth should be kept slightly open by means of one of the dental mouth-props shown in Fig. 19, p. 258, or by the chloroform prop of Fig. 53, p. 381, as Mason's gag is inapplicable. When the prop has been inserted the operation may be begun, and if swallowing and slight coughing be not abolished, sponging will be rarely if ever needed, even though hæmorrhage be free. There is often a good deal of bleeding in these cases, and if the dorsal posture be adopted, difficulties will almost certainly arise.

For operations upon the **tongue** the lateral or latero-prone posture is the best, although the "propped-up" position is still used by many surgeons. Deep anæsthesia should be secured

before the gag and nose tube are inserted. When the first part of the operation consists of tying the lingual arteries or removing affected glands, the anæsthetist's task will be easier than under other circumstances; for there will be no inconvenient tendency for the patient to recover from the effects of the anæsthetic during the insertion of the gag, etc. When a considerable portion or the whole of the tongue has been removed, the breathing may become embarrassed by the stump of the tongue and epiglottis covering the opening of the larynx. Many surgeons follow the plan of passing a ligature through the base of the organ and epiglottis before excision, in order to avert this danger; and the anæsthetist will probably be excused for suggesting the precaution, should it have been omitted. In connection with these operations it may be well to say a few words as to the advisability of tracheotomy, for the anæsthetist may be consulted upon this point. Generally speaking, this measure is unnecessary if the lateral posture be adopted. But should the patient display any considerable embarrassment in breathing when the mouth is first opened to the requisite extent by the gag, it is, as a rule, advisable to open the trachea at this juncture, for such embarrassment to breathing will be liable to increase during the course of the case.

In **staphylorrhaphy** and other operations upon the **palate** the administration of ether before chloroform is, by some surgeons, regarded as open to objection, owing to the inconvenient hæmorrhage which may result. To meet this objection the C.E. mixture may, if desired, be used to precede chloroform, or the latter may be employed throughout. The dorso-lateral posture with the head slightly extended answers very well. Many operators, however, require the patient to be placed in the semi-recumbent position with the head thrown back. Generally speaking, the anæsthesia must be profound, in order to avoid retching, coughing, or movement. In the earlier stages of staphylorrhaphy, however, when hæmorrhage is free, it is usually advisable to maintain only a moderate degree of anæsthesia. One advantage of the dorso-lateral posture is that the head can be occasionally turned well to the side for the escape of blood, should bleeding be profuse. It is necessary to

watch the pulse when working with a profound narcosis. As already mentioned (p. 42), there is often a considerable degree of intercurrent asphyxia in these cases. Many of the symptoms met with, indeed, such as cyanosis, pallor, feeble pulse, coldness of the face and extremities, and half-open lids, may be dependent upon the embarrassed breathing.

The successful removal of **tonsils** is largely dependent upon the anæsthetist. Surgeons differ so widely in their requirements, that it is difficult to lay down any definite rules of procedure. When only one tonsil requires removal; when it is of such size and shape that it may with certainty be encircled by the guillotine; and when the patient is of sufficient age to permit the preliminary insertion of a mouth-prop (Fig. 19, p. 258) or Doyen's gag, here figured, nitrous oxide and oxygen will give the best results. Pure nitrous oxide is not so satisfactory, because of its tendency to produce muscular spasm, head-movement, and general venous engorgement of the tongue and adjacent parts. Within recent years ethyl chloride has been extensively used for tonsillotomy. It produces a longer anæsthesia than nitrous oxide; there is little or no venous congestion under its influence; and it is specially applicable in the case of crying or recalcitrant children. Both tonsils may usually be successfully removed under a single administration of this anæsthetic. Doyen's gag is particularly useful, as it allows of the removal of the second tonsil without readjustment. When surgical difficulties are likely to arise, or when it is proposed to take some time over the operation, it is often a good plan to place the patient in front of a window with a

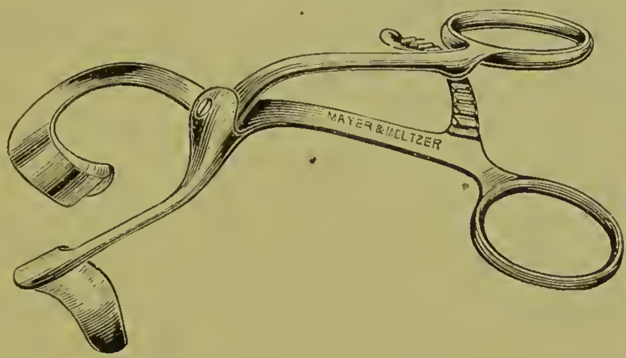


FIG. 10.—Doyen's Gag.

strong light, and to charge him up, so to speak, with ether. In this way a clear view of the tonsils may be obtained and a perfectly quiet anæsthesia, free from movement, relied upon. Under these particular circumstances frequent sponging may be needed, and if the hæmorrhage be free, the head must be tilted forwards from time to time. When the tonsils are very large, the C.E. mixture or chloroform may be the only permissible anæsthetic, as other agents would cause difficulties in breathing. The sitting posture is certainly the best for tonsillotomy, and may be safely adopted (p. 186), except when chloroform is used throughout.

The part played by the anæsthetist in operations for the **removal of post-nasal adenoid growths** is also one of considerable importance. As the most divergent views exist not only with regard to the means which should be adopted for inducing and maintaining anæsthesia, but as to the posture in which patients should be placed, the subject deserves special consideration. With the actual surgical details of the operation we are not, of course, concerned. It may be said, however, that from the anæsthetist's point of view surgeons divide themselves into two classes—those who perform the operation as quickly as possible; and those who see no necessity for or advantage in this rapidity. It would be out of place to express an opinion on the respective merits of these two schools, but speaking purely as an anæsthetist, the author must confess that the deeper and more persistent anæsthesia required by the latter system is more in harmony with the general principles which should guide us. It is certainly more satisfactory to the administrator of the anæsthetic to rapidly induce full anæsthesia and to maintain this condition till the operation is completed (which can be done with safety) than to adopt methods which may favour the occurrence of screaming, inconvenient movement, and other unpleasant or even distressing symptoms. The author regrets to say that he knows of instances in which patients have become perfectly conscious before the completion of the operation—a state of things which, with our present knowledge, hardly admits of excuse. It must, of course, be admitted that the transient and light anæsthesia which many surgeons prefer has the advantage of leaving the

patient with little or no after-effects. But the inconvenience of this inadequate anæsthesia, and the distress to the friends which it may occasion, are certainly open to great objection. Were there any real danger in keeping up satisfactory anæsthesia, the whole aspect of the question would be changed, but this is not the case. The selection of the anæsthetic will necessarily largely depend upon whether the operation is to be rapid or deliberate. If it is to be the former, ethyl chloride is probably the best anæsthetic, particularly in hospital practice, although nitrous oxide still has its advocates. The nitrous oxide-ether sequence, the C.E. mixture, or chloroform itself, are also applicable for brief naso-pharyngeal operations. With nitrous oxide or ethyl chloride, either a small dental mouth-prop should be placed between the teeth during the inhalation, so that no delay need arise in subsequently opening the mouth by the Mason's gag, or the Doyen's gag shown in Fig. 10, p. 191, may be inserted before the inhalation commences. For deliberate and more lengthy operations, the plan the author usually adopts is to administer nitrous oxide and ether till the patient has just lost his corneal reflex; a Mason's gag is then inserted; the operation is begun; and should further anæsthesia be desired, it is maintained by pumping in chloroform vapour through an oral tube, the coughing and swallowing reflexes being retained. For children under four or five years he uses the C.E. mixture or the C.E.-chloroform sequence (p. 491), according to the duration of the operation. With regard to the vexed question of posture the reader is referred to what has been said above (p. 184). The purely dorsal posture, although regarded by many as dangerous, is in reality a good one provided the depth of anæsthesia be adjusted as recommended; that blood be repeatedly sponged away by small, coarse, unattached sponges; and that the head be turned occasionally to the side for drainage. The dorsal posture with the head extended over the end of the table, although still used, is not as satisfactory as other positions (p. 185). The dorso-lateral posture, with one shoulder raised and with the head turned to one side and slightly extended, is employed by many surgeons, and is certainly preferable to the last mentioned. The semi-recumbent or "propped-up" posture

with the head neither flexed nor extended is not a good one for reasons already given (p. 186). The "propped-up" posture with the head extended is so unsatisfactory that nothing need be said about it. There are, however, certain points in favour of the sitting posture in these cases. It is certainly a very convenient one for the surgeon; and so long as the principles already laid down (p. 186) are followed, a skilful anæsthetist will be able to steer his patient perfectly through even a protracted operation. The "bent-forwards" position is only applicable under the circumstances already referred to on p. 187. Trendelenburg's position is open to the objection that it is inconvenient to the surgeon, and is liable to lead to unusual hæmorrhage. Whatever posture be adopted, the patient should be placed upon his side immediately the operation is finished; the mouth should be kept *slightly* open for a while by a Mason's gag; and he should not be left until distinct evidences of recovery are present.

Patients requiring operations within the **nasal cavities** often possess a partially or wholly occluded nasal air-way; and in such patients it is a good plan to place a little mouth-prop (Fig. 16, p. 256) between the teeth before commencing the administration. This is particularly important in muscular subjects, in whom masseteric spasm is likely to be pronounced. The sitting posture is very properly coming into more general use for intra-nasal operations (*vide supra*, p. 186). Should the anæsthetist be comparatively inexperienced, the lateral, dorso-lateral, or the dorsal posture may be chosen. Very free hæmorrhage may be met with during the removal of the turbinated bodies or "spurs," so that special care must be taken to avoid blood entering the larynx (p. 188). In all intra-nasal operations the mouth should be kept open, at all events to a slight extent, in order that the tube of the Junker's inhaler may properly deliver its vapour and that blood may be sponged out of the pharynx.

For all other operations within and about the naso-pharynx and pharnyx, such, for example, as those for the removal of **naso-pharyngeal polypi** or **tumours of the epiglottis,** the anæsthetist should proceed as has been above indicated, employing the lateral or dorso-lateral posture

whenever possible, and regulating the depth of anæsthesia as described.

Operations within and upon the Larynx and Trachea.—The administration of anæsthetics for these operations is often a rather anxious task, because of the condition of the patient at the time. Speaking generally, chloroform is preferable to all other agents; but in cases free from dyspnœa there is no objection to inducing anæsthesia with the C.E. mixture. Nitrous oxide, ether, and ethyl chloride are unsuitable anæsthetics.

For such operations as partial or complete **excision of the larynx, thyrotomy for the removal of laryngeal growths,** etc., the surgeon usually first performs tracheotomy, employing a Hahn's or Trendelenburg's tube with the object of preventing blood passing from the larynx to the trachea. In the author's experience Trendelenburg's plan of cutting off communication with the trachea by the distension of a small air-ball round the tracheotomy tube has given the best results. In one or two cases he has known the sponge surrounding the Hahn's tube to allow the passage of blood from above downwards. But whichever plan be chosen, it is certainly a mistake to adapt to the tracheotomy tube the long flexible tubing and funnel generally supplied for maintaining anæsthesia. The addition of this appliance may greatly impede breathing, the tubing becoming blocked by blood and mucus. The simplest plan is to maintain anæsthesia by a Junker's apparatus, employing a small rubber catheter, the end of which is passed a short distance down the tracheotomy tube. Apnœic pauses and almost imperceptible breathing are commonly met with immediately after the introduction of the tracheotomy tube. It is advisable to keep up as deep an anæsthesia as possible in order to prevent reflex cough and movement. Some surgeons employ an ordinary tracheotomy tube in these cases and insert a small sponge, directly the larynx has been opened, in such a way as to prevent blood passing towards the trachea. There are practically only two postures available for these operations—the dorsal with the shoulders slightly raised and the head somewhat extended, and that of Trendelenburg, already referred to (p. 187). It is well to maintain the

anæsthesia till the bandages have been applied, when the patient should be immediately turned upon his side. If this be done, mucus and blood will be readily expelled as the cough reflex returns, instead of being driven into the unbandaged wound.

Although **intra-laryngeal operations from above** are now generally performed under cocaine, it is occasionally necessary to administer a general anæsthetic, particularly in the case of children; and no other agent than chloroform is applicable. Should the patient be a child, he should be carefully anæsthetised in the dorsal posture, and when moderately deep anæsthesia has been secured, placed in a chair with the head very slightly thrown back. A Mason's gag is next inserted, the mouth-tube of Junker's inhaler introduced, and the operation begun. Considerable experience is needed before cases of this kind can be undertaken; for the anæsthetic has to be given till reflex coughing or movement cannot take place, and yet it must not be pushed to the degree of causing such a fall of blood-pressure as would be hazardous in the sitting posture. It is in these cases that the plan suggested and practised by Dr. Scanes Spicer,[1] of spraying the fauces with a dilute cocaine solution, is of service, for it allows of a lighter general anæsthesia than would otherwise be possible. The cocaine not only lessens irritability but also hæmorrhage and salivation. The author has administered chloroform in conjunction with cocaine on many occasions, and can speak well of the plan. The pulse should be carefully watched throughout.

The author has only once had to anæsthetise an adult for the removal of an intra-laryngeal growth from above. The patient was a gentleman of about sixty years of age, tall, rather stout, and liable to bronchial attacks. Anæsthesia was induced with the C.E. mixture, the patient sitting in a chair. A change was then effected to chloroform, which was pushed till the laryngeal reflex vanished.

For **laryngotomy** and **tracheotomy**, chloroform is also the best anæsthetic. It should be given throughout in all cases in which difficult breathing pre-exists; but when no such difficulty is present there is no objection to inducing anæs-

[1] See *Brit. Med. Journal*, vol. ii. 1894, pp. 1171 and 1276.

thesia by other means. The remarks just made as to the posture of patients for thyrotomy apply in this connection. Apnœic pauses often arise immediately after the introduction of the tube.

The plan of administering **morphine in conjunction with chloroform** is regarded by many Continental surgeons as specially advantageous in major operations within and about the mouth or nose, owing to the very small quantity of anæsthetic needed to keep up anæsthesia, or, more correctly speaking, analgesia. For remarks on this mixed narcosis, see Chap. XVI. p. 501.

Except as the result of hæmorrhage, **surgical shock** primarily circulatory in type is rarely if ever met with in operations of this group. This is exceedingly fortunate, for were it otherwise it would be hazardous to employ chloroform in the sitting posture. The exaggerated breathing necessarily incidental to operations of this class is doubtless a powerful factor in maintaining good circulation.

B. DENTAL OPERATIONS

Choice of Anæsthetics, etc.—The anæsthesia produced by **nitrous oxide with small percentages of oxygen** is the best with which we are acquainted for dental operations. Its chief merits are that it is practically free from risk to life and that it is applicable, with the rarest possible exceptions, to all subjects. When the diet has been regulated, all constricting clothing unfastened, a proper posture secured, and the administration conducted as described on p. 306, an almost ideal form of anæsthesia may usually be obtained. The average available duration of this anæsthesia, for a dental operation, is 44 seconds. As the anæsthesia is of a deeper character than that obtainable by other methods of administering nitrous oxide, patients' relatives and friends who may be present or within earshot are not distressed by reflex screaming or movement. Stertor and lividity, moreover, are conspicuously absent in the vast majority of cases. As regards after-effects, these are very rarely met with when attention has been paid to the diet. The chief, one might almost say the only,

disadvantage of this form of anæsthesia is that it is of insufficient duration when it is desired to remove numerous firmly-rooted teeth at one sitting.

When it is impracticable to administer nitrous oxide as above described, it must either be given **with air** (p. 294) or in a state of **purity** (p. 267). The anæsthesia from nitrous oxide and air is of a better type than that produced by the undiluted agent; but in neither case is it possible to secure such good results as when oxygen is mixed with the nitrous oxide.

Various means have been devised for **prolonging nitrous oxide anæsthesia** in dental surgery. Thus, the face-piece of an apparatus supplying nitrous oxide and oxygen or pure nitrous oxide may be reapplied as the patient begins to emerge from anæsthesia, care being taken that the body is nearly vertical and that the head is not extended when the face-piece is reapplied. Should this precaution not be observed, respiratory embarrassment from blood, tooth fragments, or the swollen tongue may occur. When properly managed, the re-application of nitrous oxide and oxygen or nitrous oxide itself often proves of great service to the operator. In the case of nitrous oxide and oxygen the apparatus should be reapplied with the oxygen indicator at "0," "1," or "2," and the oxygen percentage should then be quickly increased. In this way several teeth may be removed at one sitting, and when the diet has been carefully regulated, very good results, so far as the patient is concerned, may be obtained. Another plan of prolonging nitrous oxide anæsthesia, and one which is spoken of highly by many anæsthetists, is to first induce nitrous-oxide anæsthesia in the usual way, and to continue the administration by means of the nose-piece (p. 297). It must be remembered, however, that all these methods of prolonging nitrous oxide anæsthesia are open to the objection that they may be attended by stertor, obstructed breathing, cyanosis, and the usual reflex accompaniments of light nitrous oxide anæsthesia. From the point of view of patients requiring the removal of many teeth at one sitting, prolongation methods are certainly a great boon; but they need to be applied with discretion and caution if good results from all points of view

are desired. In private practice the removal of one, two, or three firmly-rooted teeth at one sitting is all that is generally required, and as this can almost invariably be accomplished under nitrous oxide and oxygen without any unpleasant sensations, so far as the patient is concerned, during or after the administration, and without any distress to relations or friends who may be present, this line of procedure leaves little or nothing to be desired.

During the last few years **ethyl chloride** and mixtures consisting largely of this substance have come into extensive use as anæsthetics for dental operations. But from the numerous deaths which have been recorded in connection with the administration of these bodies, it is impossible to avoid the conclusion that, *cæteris paribus*, ethyl chloride is greatly inferior to nitrous oxide in point of safety. It is certainly an exceedingly portable and convenient anæsthetic; its vapour is not unpleasant to inhale; it is easy to administer; and it rapidly produces a deep available anæsthesia half as long again as that obtainable by nitrous oxide. Recovery from its influence, however, is more often associated with nausea, vomiting, and headache than the recovery from nitrous oxide. The important question to consider is: To what extent are we justified in availing ourselves of the special advantages of this anæsthetic when we have at our disposal a body such as nitrous oxide which is far safer and which is rather more pleasant to inhale and certainly less liable to be followed by unpleasant after-effects? Ethyl chloride is undoubtedly useful in busy hospital practice and in country private practice; and when administered with a proper knowledge of the principles of anæsthetisation, and by one who has had experience in its use, there is little to be said against its employment for the ordinary run of dental operations. But when nitrous oxide is available, and when not more than two firmly-rooted teeth have to be removed at one sitting, this anæsthetic is, as a general rule, unquestionably preferable to ethyl chloride. At the same time there are certain special cases in which ethyl chloride is to be preferred to nitrous oxide. Thus, when a few temporary teeth require removal from a crying or recalcitrant child, or when previous experience

has shown that a particular patient is an unsatisfactory subject for nitrous oxide, ethyl chloride may, in skilled hands, be the appropriate agent. The sequence of nitrous oxide and ethyl chloride is also useful under certain circumstances (p. 495).

For **difficult or prolonged dental operations**, *i.e.* for those which do not admit of performance under an ordinary administration of nitrous oxide, nitrous oxide and air, nitrous oxide and oxygen, or ethyl chloride, the anæsthetist must either employ the nasal method of administering nitrous oxide (p. 297), or he must resort to the routine methods of anæsthetisation which are suitable in general surgical practice. Patients with more or less complete trismus fall into this category even though only one tooth has to be removed. As regards the choice between a prolonged nitrous oxide administration on the one hand and ordinary surgical methods on the other, much must depend upon the experience and aptitude of the anæsthetist. Nasal anæsthetisation by means of nitrous oxide is not invariably successful, at all events from the points of view of the operator and anæsthetist. Reflex movement, loud phonation, obstructed breathing, and rigidity are not uncommon, so that it is generally preferable to place patients requiring these operations well under ether. The perfect quietude thus obtainable is often essential to a successful operation. After a little practice the anæsthetist will find that he can, by regulating the length and degree of etherisation, provide the surgeon with an available anæsthesia of the desired duration, so that no reapplication of the inhaler will be needed. It is a good plan, in these major dental operations, (1) to first remove the lower and upper teeth of one side; (2) to tightly wedge a large sponge between the gums of that side; (3) to complete the operation; and (4) to similarly plug the other side of the mouth. In this way loss of blood may be largely prevented. As regards after-effects in these cases, it is worthy of note that by arranging the early morning or 1 P.M. for the administration, the patient in the former case having had nothing to eat or drink since the preceding evening, and in the latter having had only tea and toast at 8 A.M., remarkably little discomfort will follow the use of ether. If the

anæsthetist be experienced, the best results, in major dental operations, will be obtained with the nitrous oxide-ether-chloroform sequence, which may be safely employed, for suitable patients, even though the sitting posture be adopted (p. 186). Although chloroform is not a suitable routine anæsthetic in dental surgery when given *ab initio*, it may be used *after ether*, provided the special precautions already referred to when dealing with throat operations be followed. In this way the author has anæsthetised a considerable number of patients, not only for major dental operations but for the excavation of sensitive teeth prior to stopping. Although he has usually employed only a moderate anæsthesia in these cases, he has never seen any indication of reflex circulatory shock. It is often convenient to use a Junker's inhaler with a nasal tube during lengthy dental operations. Patients who, by reason of visceral or other affections, are suitable only for chloroform or its mixtures, should be anæsthetised in the dorsal posture and turned to one or other side for the operation.

Children are rapidly affected by pure nitrous oxide and rapidly recover from its influence. They are liable to inconvenient epileptiform movement and to reflex phonation. Much better results are obtainable by nitrous oxide and oxygen; but it is important, when using this mixture, to carefully diet the patient. Boys and girls of from ten to sixteen seem specially liable to nausea after a full administration of nitrous oxide and oxygen. As already mentioned, ethyl chloride is very useful in small children.

Posture.—The posture during anæsthetisation for dental operations is important. The body should be nearly but not quite vertical; the head in the body-line, *i.e.* neither flexed nor extended; the legs straight; and the feet projecting over the foot-rest in such a way that the tendo Achillis of each foot rests upon the rail. Should the operator wish the patient's body to be nearer the horizontal plane, the chair should be thrown back immediately before the face-piece is removed. Similarly, should he desire the head extended, extension may be effected just as the administration terminates. It must be borne in mind that there is a risk, during operations upon

semi-recumbent patients and upon patients with the head extended, of extracted teeth or roots falling backwards. Reference has been made above to the use of chloroform when the patient is in the sitting posture, and to the necessity for the dorsal or lateral posture when this anæsthetic is given *ab initio.*

Mouth-props.—All mouth-props should be sterilised by boiling. The best form of prop is shown in Fig. 19, p. 258. When trismus exists, a small prop should, if possible, be placed between the front teeth in order that the mouth may be opened without delay by the Mason's gag when anæsthesia is complete. When ether or chloroform anæsthesia is to be induced, no prop need be used during the induction stage unless the nasal air-way be inadequate (p. 165).

C. OPERATIONS IN THE REGION OF THE NECK NOT INVOLVING THE AIR-PASSAGES

In administering anæsthetics for operations **involving the great vessels and nerves** of the neck the following points must be borne in mind :—

(1) Any embarrassment in respiration will be quickly followed by considerable venous turgescence, which may inconvenience the operator. It is hence desirable to avoid all coughing, straining, and hampered respiration, by maintaining a deep anæsthesia.

(2) Ether leads to greater vascularity than chloroform. When, however, ether is administered with a sufficient supply of air, and respiration is regular and unembarrassed, there is very little difference between the effects of the two anæsthetics. The vascularity under ether is greater in the first ten minutes of the operation than later on.

(3) In some cases considerable surgical shock may arise during the operation, either from loss of blood or from interference with important nerves. In addition to Illust. Cases, No. 57, p. 579, and No. 58, p. 579, in which chloroform was used, the author has notes of one other in which considerable circulatory depression took place under ether after the internal

jugular vein had been tied, and whilst the internal carotid was being exposed for ligature.

(4) There is a distinct though slight risk of air entering veins during these operations (see p. 587). Sternberg[1] has recorded two instances in which gurgling cardiac sounds, due to the presence of air within the heart cavities, were audible after the accident had occurred.

For operations upon the **thyroid gland** chloroform is the best anæsthetic. It may be preceded by the C.E. mixture in cases unattended by dyspnœa or other respiratory symptoms. Nitrous oxide, ether, and ethyl chloride are inadmissible in these cases. A fairly deep chloroform anæsthesia may be secured in cases in which there is no dyspnœa or cyanosis and the tumour is easy of removal. Although light anæsthesia may embarrass the surgeon, it is the only permissible state when dyspnœa is present beforehand, or when surgical shock begins to show itself during the operation. When bronchial catarrh or chronic bronchitis co-exists with a narrowed trachea, special care is needed. The risk is that mucus may be coughed up to the narrow part of the trachea and there remain, becoming the immediate cause of respiratory failure. Cyanosis during anæsthetisation must be regarded as indicating the need for a light anæsthesia.

Patients requiring operations for **mastoid** disease are best anæsthetised, as a rule, by the nitrous oxide-ether-chloroform sequence. The anæsthetist should maintain purely *oral* breathing in these cases: otherwise inconvenient vascularity of the parts may be met with. The author has never seen surgical shock in connection with any operation upon the mastoid process.

Reference has already been made (p. 167) to the anæsthetisation of patients suffering from **angina Ludovici**, and to the special care which is necessary in such cases.

Recovery from the effects of the anæsthetic may be more tardy than usual after neck operations, owing to the tight bandaging which is often necessary. The anæsthetist should not leave his patient till distinct signs of returning consciousness have been manifested.

[1] *Centralbl. f. Chir.*, No. 11, 1899.

D. OPERATIONS INVOLVING THE PLEURA OR LUNG

Patients requiring operations for **empyema** or for other affections of the pleuræ or lungs are, as a rule, suffering at the time from respiratory difficulties more or less pronounced. The reader is therefore referred to the previous chapter (p. 164) for remarks bearing upon the use of anæsthetics in persons thus affected.

The **posture of the patient** in these cases is a matter of importance. Should the lateral position be necessary, the affected or more affected side should, if possible, be lowermost, in order to allow of the free expansion of the healthier lung. Unfortunately, many operations upon the pleura or ribs cannot be performed unless the affected side be uppermost, or the patient be lying almost prone. The prone, or semi-prone, position is an unsatisfactory one under any circumstances, as it is liable to interfere with respiration; but it is more especially hazardous when a considerable proportion of the trunk-weight is allowed to tell upon the only efficient lung. The administrator should at all events *induce* anæsthesia whilst the patient is lying in a favourable position; and then observe whether any effects follow the change of posture. In chronic cases, in which the healthier lung has become enlarged and accustomed to increased work, posture is not of nearly so much importance as in more recent cases.

When a **purulent or gangrenous cavity** of the lung or pleura communicates with the bronchi, special attention must be paid to posture; otherwise respiration may become embarrassed by pus, gangrenous matter, or blood obstructing the air-ways (see p. 541).

During the **withdrawal of fluid** from the pleural cavity the circulation of the patient should be watched, and any signs of failure reported to the operator. Syncope is said to have occurred from the sudden return of the heart to its proper position. The author has never witnessed any symptoms of this nature.

Operations upon the lung may be attended by **hæmoptysis** during the administration, and it is hence desirable, in such

operations, to keep the patient upon his affected side, so that the bronchi of the unaffected lung may remain as free as possible for respiratory purposes (see Illust. Case, No. 46, p. 541).

With regard to the **most appropriate anæsthetic,** it is difficult to lay down definite rules. The condition of the patient must be the chief guide (see p. 168).

E. ABDOMINAL OPERATIONS

When an anæsthetic is required for an **abdominal examination** it must be administered to the full surgical degree. The subjoined remarks, which more particularly apply to anæsthesia for abdominal section, are hence applicable. In selecting an anæsthetic for a simple examination, the type of subject is of paramount importance. Nitrous oxide and ethyl chloride are inadmissible by reason of the muscular rigidity they so often induce. Ether, if given at all, must be used freely. Caution is necessary with chloroform or a chloroform mixture lest in attempting to obtain muscular relaxation the bounds of safety be overstepped. In the case of chloroform or its mixtures a slow and progressive administration is advisable till the necessary degree of muscular relaxation has been attained. Muscular patients in a good state of health, and particularly florid boys, may require such a profound degree of anæsthesia in order to abolish inconvenient rigidity, that if chloroform or a chloroform mixture be the anæsthetic chosen, the greatest caution must be exercised. Boys and girls suffering from naso-pharyngeal catarrh are specially liable to give trouble (p. 165). Such patients should be carefully prepared and kept without food for many hours before the administration.

The successful performance of abdominal operations depends in no small degree upon the skill, judgment, and self-possession of the anæsthetist. In the first place, patients requiring these operations are often in a very unsatisfactory condition. Secondly, abdominal operations are frequently attended by surgical shock (p. 212). Thirdly, unless the level of anæsthesia be properly adjusted—and there are, perhaps, no cases in which there is such a need for what may be termed the fine adjustment of anæsthesia as abdominal cases—there may be on

the one hand such inconvenient phenomena as reflex movement, abdominal rigidity, retching and vomiting, or on the other, such threatening phenomena as pallor, pulselessness, or arrested breathing. Lastly, unless care be taken in the selection and use of anæsthetics for abdominal cases, the after-effects may be such as to retard or possibly prevent the recovery of the patient. As will be subsequently pointed out (pp. 359 and 601), patients who have undergone abdominal operations are specially liable to respiratory sequelæ.[1]

In order that the best results may be obtained, attention must be paid to (*a*) the preparation of the patient; (*b*) the selection of the anæsthetic and method of administration; (*c*) the posture; (*d*) the depth of anæsthesia; and (*e*) the particular operation and its tendency to produce surgical shock.

(*a*) **Preparation of Patient.**—Unless special circumstances be present, the **diet** should be carefully regulated, as described on p. 226.

When the **stomach is distended with fluid**, as may be the case in patients suffering from intestinal obstruction, pyloric disease, etc., general anæsthesia may be hazardous owing to the risk of vomited fluid entering the larynx and trachea, and producing asphyxial symptoms upon the table, or fatal pneumonia subsequently. Under these circumstances it is advisable either to wash out the stomach before the administration, or to do this during the induction stage. The latter course is generally preferable, and should be chosen. The patient must be kept upon his side during the process.[2] (See also remarks on pp. 174 and 213.)

[1] According to Dr. G. E. Armstrong of Montreal (*Brit. Med. Journ.*, 19th May 1906, p. 1141) "Henle reports 1787 abdominal operations, followed by 143 cases of pneumonia, or 8 per cent, with a mortality of 65, or 3·6 per cent. Czerny, 1302, with 52 cases, or 3·9 per cent, of lung complications. Kummell, 1754 laparotomies, with 43 cases, or 2·5 per cent. Kausch, from Mikulicz's clinic, 1881, with 45 cases, or 2·33 per cent."

[2] We are indebted to the late Mr. Greig Smith for some valuable remarks in this connection. (See *Brit. Med. Journ.*, 12th March 1892, for an abstract of Mr. Greig Smith's paper, which was read before the Roy. Med. and Chir. Soc. on 8th March 1892, and was entitled "Enterostomy in Intestinal Obstruction.") He urged that general anæsthesia should never be induced when the stomach is full of fluid. The viscus should be artificially evacuated; or a local anæsthetic employed. See also *Lancet*, 25th September 1897, p. 786, for other remarks on this subject. Mr. Hugh Rigby informs the author that he has obtained good results by allowing the stomach tube, which has been used for the lavage, to remain *in situ* during the operation. He points out that although the stomach

Special care should be taken to **wrap the patient up warmly.** For desperate cases a hot-water bed may with advantage be used. The temperature of the room should be from 65° to 70° Fahr., and there should be no draughts of cold air. With the object of not keeping their patients an unnecessary length of time under the anæsthetic, many surgeons prepare the skin by washing, antiseptic compresses, etc., before the anæsthetic is given.

(*b*) **Selection of Anæsthetic and Method.** — Putting on one side for the moment those exceptional cases in which the patient's general condition is such that some particular agent is indicated (*vide* Chap. VI.), the question arises: Is there any anæsthetic which is specially adapted for routine use in abdominal operations? In the present state of our knowledge this question hardly admits of any other than a negative answer. Much will, of course, depend upon the experience of the anæsthetist. As will be pointed out below (p. 210), it is, as a general rule, necessary to secure profound narcosis during most intra-abdominal procedures; and if the anæsthetist be not experienced in the use of chloroform and its mixtures, it will probably be advisable for him to employ ether. Should he elect, however, to use chloroform, this agent may with advantage be administered by means of some regulating apparatus (p. 370). In the hands of the experienced, ether, the C.E. mixture, or chloroform may be employed, as circumstances may dictate, and the ordinary methods of administration practised. Ether undoubtedly has certain striking advantages in this branch of surgery. Thus, its administration is less frequently complicated by laryngeal spasm than the administration of chloroform; its vapour may, in the vast majority of cases, be safely pushed till all tendency to coughing, retching, and abdominal rigidity has subsided; whilst surgical shock is far less common during operations of this class performed under its influence than during similar operations performed under chloroform. Ether is, however, liable in some cases to produce excessive salivation,

may have been emptied by the washing-out process before the operation, it may again become partly filled with regurgitated fæcal fluid during the operation. He has known as much as two pints of this fluid to escape from the stomach tube whilst he has been operating.

laboured breathing, inconvenient vascularity of parts, a persistently unpleasant taste after the administration, and occasionally, as after-complications, bronchial catarrh, broncho-pneumonia, or acute pulmonary œdema (p. 359). Chloroform, on the other hand, has its own special advantages in abdominal surgery. Respiration under its influence is comparatively quiet: the parts under operation are not inconveniently vascular; it leaves behind it fewer unpleasant after-effects than ether; and its administration, even for protracted periods, is very rarely followed by bronchial or pulmonary complications. But, like ether, chloroform has its special drawbacks. It is, as we have seen, a more dangerous anæsthetic than ether during the administration period; there is greater difficulty with it than with ether in gauging the proper level of anæsthesia; should the patient be lightly anæsthetised he will be liable to reflex movement, abdominal rigidity, and occasional retching or vomiting; and should he be deeply anæsthetised the operation may be attended by surgical shock. The C.E. mixture is often of great value in abdominal operations. One might almost go so far, indeed, as to say that it more frequently meets the requirements of the anæsthetist than any other agent. Its chloroform corrects the disadvantages of ether; its ether corrects the disadvantages of chloroform; whilst each anæsthetic exerts its own specific influence for good. The C.E. mixture may either be administered after any of the induction sequences, the best of which is the nitrous oxide-ether sequence (p. 479); it may be given after nitrous oxide (p. 493); or it may be used throughout (p. 462). Finally, there are, perhaps, no operations which more frequently necessitate a change in anæsthetic than these now under consideration. A change from chloroform or the C.E. mixture to ether is often called for in order to secure complete relaxation, or to correct reflex circulatory depression, whilst a change in the reverse direction may be needed in order to successfully treat coughing, laboured breathing, or other symptoms. As elsewhere pointed out (p. 492), great caution must be exercised in changing from ether to chloroform, particularly when the patient is deeply anæsthetised and there is much mucus within the upper air-passages.

The remarks already made concerning the selection of anæsthetics for operations upon children apply in the present connection (Chap. VI. pp. 153 and 154). Should abdominal rigidity occur under chloroform or the C.E. mixture, it may usually be quickly removed by changing to ether.

The anæsthetisation of **infants**, and particularly of infants but a few weeks old, for intra-abdominal operations is not an easy task. The successful performance, for example, of such an operation as pyloroplasty is in no small degree dependent upon the anæsthetist.[1] In some cases in which it has been necessary to secure a profound degree of anæsthesia for a comparatively short time, *e.g.* half an hour, the author has used ether in preference to any other agent, and has been very pleased with the result. The rapid respiration is but a trifling disadvantage as compared with the great advantage of obtaining abdominal relaxation with safety.

In the case of persons **desperately ill**, through some intra-abdominal condition for which laparotomy has to be performed, the author generally finds the C.E.-ether sequence advisable. When the patient is already poisoned by septic absorption, remarkably small quantities of anæsthetic are generally needed.

Patients about to undergo abdominal operations are sometimes under the influence of **opium** or **morphine**, in which case general anæsthetics must be given sparingly. Should it be found impossible to overcome abdominal rigidity by the usual means (p. 521), a subcutaneous injection of morphine may be given during the administration.

(*c*) **Posture**.—The reader is referred to the following chapter for remarks on this important subject (p. 237). Should the dorsal position be chosen, the head should be placed so that one cheek rests upon the pillow. The chief point in connection with posture during abdominal operations is that the Trendelenburg position is an exceedingly satisfactory one, so far as the anæsthetist is concerned. Provided that the patient's head be kept in a line with the body, and that a free air-way be

[1] See a paper by Dr. Edmund Cautley and Mr. Clinton Dent (*Trans. Royal Med. Chir. Soc.*, vol. lxxxvi.). The authors say "it would be difficult to imagine a class of cases in which more depends upon the skill and judgment of the anæsthetist."

maintained, respiration will remain unembarrassed, whilst reflex surgical shock of the circulatory type will be immeasurably less common in this than in the horizontal posture, even though the patient be deeply under chloroform (p. 241). The second point is that, unless care be taken in the adjustment of the arms during protracted abdominal operations, certain posture paralyses will be liable to occur (p. 247). The third point is that the surgeon sometimes finds it necessary, particularly for operations upon the gall-bladder, to place a sand-bag or hard pillow under the lower part of the thorax, with the result that some respiratory embarrassment takes place. Lastly, in extreme abdominal distension, it may be necessary to anæsthetise the patient in the sitting or semi-recumbent posture, and to gradually lower the body as the distension is relieved (p. 474).

(*d*) **Depth of Anæsthesia.**—Patients whose general condition is good may usually be safely kept in a state of deep anæsthesia, provided that attention be paid to the points above discussed, and to the circumstances under which surgical shock is likely to arise (*vide infra*). But whilst most surgeons require this complete narcosis, at all events during the important stages of the operation, there are some who are content with a light form of anæsthesia. Certainly light anæsthesia has the advantage that the patient is *less* likely to display symptoms of surgical shock of a primarily circulatory type than when deeply anæsthetised (p. 253). It may, indeed, be said that provided a corneal reflex be retained, and watchful attention be paid to the respiration (which, as we have seen, is more liable to become deranged in light than in deep anæsthesia), the patient's general condition will usually remain satisfactory, unless, of course, excessive hæmorrhage take place, or the operation be very prolonged. But the accompaniments of a light anæsthesia are often so inconvenient to the surgeon that delicate intra-abdominal operations may be well-nigh impossible. The result is that a very important task devolves upon the anæsthetist—that of providing the surgeon on the one hand with the requisite degree of abdominal relaxation, and that of safely steering the patient on the other through the deeper levels of anæsthesia. This task may be specially difficult with chloroform as the anæsthetic, and with

the patient in the horizontal posture. As a general rule, however, it may be safely accomplished by carefully observing the numerous guides as to the depth of anæsthesia. In most cases an almost imperceptible degree of lid-reflex in one eye (the reflex of the other eye having vanished) indicates the proper degree of anæsthesia. With the C.E. mixture and *a fortiori* with ether, a deeper anæsthesia than this may be secured in horizontally placed patients without that risk of surgical shock which undoubtedly obtains in abdominal operations when chloroform is freely pushed. Should the Trendelenburg posture be adopted, profound anæsthesia is apparently quite as safely secured by chloroform as by the C.E. mixture, or even by ether. Very large quantities of anæsthetic may be needed to produce the necessary degree of abdominal relaxation in young, muscular, or alcoholic subjects. Young men who have led out-door lives, and who have drunk or smoked to excess, often severely tax the resources of the anæsthetist. Patients whose general condition is fairly good are more liable to evince reflex phenomena in response to intra-abdominal stimuli than weakly persons.

In anæsthetising children it is usually necessary to secure full narcosis, as they are peculiarly liable to retching and vomiting. Healthy-looking boys and girls usually prove to be difficult subjects for such operations as appendicectomy, particularly if they are suffering at the time from nasal or naso-pharyngeal catarrh, post-nasal growths, enlarged tonsils, or allied conditions. The author finds it a good plan in such cases to artificially induce vomiting by passing the finger into the pharynx during the induction stage. The stomachs of patients of this class almost invariably contain swallowed mucus at the time of the administration; and by thus artificially inducing emesis before the operation commences, it will be found easier to obtain and retain a proper level of anæsthesia.

Feeble or elderly subjects generally pass through abdominal operations with little or no trouble to the anæsthetist. Whilst in the case of vigorous patients it is generally necessary to keep the corneal reflex in abeyance, or only very slightly present, as indicated above, throughout the administration, it is usually unnecessary and unadvisable to abolish this

reflex in the case of feeble and bad subjects. As in other branches of surgery, the feebler the patient the smaller will be the quantity of anæsthetic needed.

(*c*) **The particular Operation: Surgical Shock.**—Intra-abdominal operations have a special interest for the anæsthetist in that they frequently produce reflex, respiratory, and circulatory phenomena, thus converting what would otherwise be simple surgical anæsthesia into the complex state (pp. 41 and 252). Few, if any, abdominal sections are performed without the surgical procedure in some way or another thus modifying the anæsthesia. The modification may be so slight as to escape attention; it may be so grave as to apparently threaten life. It may come into play during the lightest anæsthesia; it may manifest itself during the most profound narcosis. Reflex respiratory phenomena are most common during the earlier stages of anæsthesia; whilst reflex circulatory phenomena are most frequently met with when the full effects of the anæsthetic have been secured. Manipulations within the upper part of the abdominal cavity have a tendency to bring about a somewhat strained and rapid type of respiration with tense muscles. An almost characteristic expiratory "catch," sometimes phonated, is common during manipulations in the region of the liver. Traction upon the peritoneum, omentum, uterus, or ovary frequently excites reflex laryngeal spasm, resulting, perhaps, in some embarrassment to breathing. Sponging out Douglas's pouch, and other procedures of a similar character, may also induce respiratory modifications likely to temporarily interfere with the convenience of the surgeon. Should the respiratory derangement assume grave proportions, the state to which the term "respiratory shock" has been given will arise. The most important of the intercurrent conditions, however, which may be met with during abdominal operations and modify the phenomena of deep anæsthesia, is undoubtedly circulatory shock. A variable degree of this form of shock is common in abdominal sections under chloroform, when the anæsthesia is profound and when the patient is horizontal. If the chloroform anæsthesia be not profound, or if it be profound and the patient be in the Trendelenburg posture, primary circulatory shock is exceptional. The complication, moreover, is less common

under C.E. mixture, and less common still under ether than under chloroform, even though the anæsthesia be deep and the patient horizontal. When the conditions are favourable to the occurrence of this form of shock, manipulations in the neighbourhood of the solar plexus, evisceration in the course of appendicectomy, traction upon the uterus, ovary, or omentum, and similar procedures, may readily cause sudden circulatory depression, the symptoms of which are very likely to be erroneously referred wholly to the anæsthetic. The clinical aspects of surgical shock will be specially discussed in the following chapter (p. 252).

Patients with acute **intestinal obstruction** are not good subjects for general anæsthesia, chiefly because of the risk of vomited fluid entering the larynx during the administration. Reference has above been made (p. 206) to the importance of washing out the stomach in these cases. Under any circumstances the administrator should make it a rule to keep the head turned well to one side throughout; for vomiting may come on very quietly, and if he be not on the watch he may suddenly find his patient verging on asphyxiation. In desperate cases, and especially in those in which the patient is very obese, the author generally places a pillow under one shoulder, turns the head well to the opposite side, inserts a Mason's gag between the teeth or gums, and has at hand small sponges for keeping the pharynx clear of fluid. He once anæsthetised, for the relief of acute obstruction, a patient who weighed over twenty stone: she had a dilated, fatty, and very irregular heart, and was vomiting blood every ten minutes. In this case the surgeon kindly consented to operate whilst the patient was lying almost in the lateral posture, and the author ascribes the successful issue of the administration to this fact. The patient died some hours afterwards, but without any signs of fluid having passed into the trachea. Patients requiring these operations will often be found to be partly under the influence of morphine or opium. The anæsthetist should ascertain this point; for, should an opiate have been given, very little anæsthetic may be needed (see remarks on p. 505). Ether often cannot be employed when the abdomen is greatly distended and the respiration

hurried; the best anæsthetic under such circumstances appears to be the C.E. mixture, given upon a Skinner's mask, as described in Illust. Case, No. 17, p. 474. Should ether be preferred, and it may often be advantageously chosen for the more chronic cases, the asphyxial element of the bag inhaler must be used with caution. If the patient be very weak, the semi-open method should be employed.

It is usually taught that there is some risk of heart failure during the **evacuation of fluid** from a distended abdomen. It is probably more correct to say that if the patient be deeply under chloroform vaso-motor syncope from a sudden fall in the intra-abdominal tension may result. The anæsthesia should be light during such operations. With this precaution it will generally be found that the respiration, and with it the pulse, will improve during, and immediately after, the evacuation of the fluid (see Illust. Case, No. 16, p. 474).

Flushing out the abdomen with hot water usually improves the respiration, the pulse, and the colour of the patient, whilst it not uncommonly sets up a reflex crowing condition of breathing. After the flushing is over, however, the pulse is apt to flag.

F. OPERATIONS UPON THE GENITO-URINARY ORGANS AND RECTUM

It has already been pointed out (p. 78) that the genito-urinary and rectal reflexes are amongst the latest to disappear, so that a **profound anæsthesia** is necessary during operations of this class. Unless the patient be fully anæsthetised, inconvenient or even threatening symptoms of a respiratory, and not, as is often supposed, of a circulatory, nature may be reflexly excited. General movement, laryngeal stridor, stertor from tongue retraction, and respiratory spasm may thus complicate the administration in certain subjects, if the operation be begun before full narcosis has become established (see Illust. Case, No. 42, p. 536). This point becomes of vital importance in patients whose circulatory system is so feeble or degenerate as to be unable to withstand a slight asphyxial strain. Patients suffering from affections of this group are often highly nervous, peculiarly sensitive, and prostrated by continued pain

and sleeplessness. They hence require considerate and careful management. Whenever practicable, **ether** should be used in preference to other anæsthetics, for it may be safely pushed to that point at which little or no reflex response will follow the commencement of the operation.

It is generally believed that the operation of **castration** is liable to be attended by grave shock; but although the author has watched for this condition in a large number of cases, he has never seen it. He has, however, once or twice observed a distinct change of pulse, undoubtedly due to the exposure or removal of the testis, the rate becoming abruptly slower, or some intermission taking place. Such changes are probably more common under chloroform than under ether—the anæsthetic which the author has generally administered (see remarks, p. 253). Crile observed a considerable fall of blood pressure during **amputation of the penis** in an old man.[1]

Patients suffering from **bladder affections** are usually elderly, and are not unfrequently the subjects of obesity, emphysema, and chronic bronchitis. They are hence often unsuitable for ether, and a deep anæsthesia has to be secured with the C.E. mixture or chloroform. Distension of the bladder in a patient whose breathing is principally diaphragmatic will at once increase the rate and depth of respiration. There is, perhaps, no greater problem in the administration of anæsthetics than that of keeping the breathing of an emphysematous patient sufficiently quiet to meet the requirements of the operator, when the bladder, and possibly the rectum, have been artificially distended preparatory to a supra-pubic operation.

The administration of anæsthetics for the operation of **prostatectomy** is often a matter of some difficulty. Whilst chloroform may be the only permissible anæsthetic by reason of the age and condition of the patient, it may be almost impossible, with this agent, to safely abolish all inconvenient reflexes. Sometimes the C.E. mixture answers better than chloroform itself. Although abdominal rigidity may usually be corrected by a change to ether, the use of this anæsthetic in cases of this class is so likely to be followed by pulmonary

[1] See Mummery's "Lectures on Surgical Shock," *Lancet*, 18th March 1905, p. 698.

complications that one should rarely if ever employ it. It is not improbable that future observations may indicate the advantages of a small dose of morphine either before or during the anæsthetisation of patients requiring prostatectomy. Mr. Carter Braine,[1] who has had a large experience in the use of anæsthetics for this particular operation, speaks highly of a mixture of chloroform with one-twelfth of ether.

In operations upon the **kidney** there is often considerable surgical shock, and as a general rule ether is therefore preferable to chloroform. The shock is likely to be greater in feeble than in moderately healthy persons (see Illust. Case, No. 67, p. 584). The question of posture in these operations will be discussed in the following chapter.

Full-blooded, well-nourished patients and those in average health generally pass through **rectal operations** without giving any anxiety to the anæsthetist, always provided that ether be employed, and that deep anæsthesia be secured. Reflex laryngeal stridor, of a pitch which is almost characteristic of rectal manipulation, is very common in these cases, particularly whilst the sphincter is being dilated. During the more extensive procedures, in which numerous nerves are divided, some degree of circulatory shock may appear, even under ether. This complication is most frequently observed in overworked, sparely built, and anæmic subjects. There is usually a considerable degree of surgical shock in connection with excision of the rectum and with Kraske's operation. During the removal of a portion of the sacrum in the course of the latter procedure the author has known both radial pulses to disappear and to remain absent for twenty minutes, although breathing continued. In this operation the anæsthetist must guard against intercurrent asphyxia, due to the prone posture (p. 550).

G. OPERATIONS UPON THE BREAST

There is a greater liability to **surgical shock** during breast operations than is generally believed, and the anæsthetist should therefore do all in his power to aid the surgeon in preventing and treating this condition. Signs of circulatory

[1] See *Lancet*, 10th March 1906, p. 677.

depression may appear as the immediate result of the skin incision, as a sequel to hæmorrhage, or as the consequence of the exposure and manipulation of a large raw surface. The patients most liable to surgical shock are those whose general condition is unsatisfactory, and those who are subject to attacks of fainting. The operations most likely to induce this condition are those in which a large surface is exposed and a good deal of blood lost. The symptoms generally come on at that part of the operation which immediately precedes the actual removal of the breast. One of the most acute cases of surgical shock that the author ever witnessed took place in connection with a breast operation (see Illust. Case, No. 54, p. 577), but in this case the symptoms were due to forcible muscle-traction. In cases of shock the state of the patient almost invariably begins to improve immediately the removal of the breast has taken place. The reader is referred to the following chapter for further remarks on this subject (p. 253).

With regard to the **most appropriate anæsthetic**, this must be decided by a careful consideration of the patient's general state of health. The nitrous oxide-ether-chloroform sequence answers well in most cases. Other things being equal, patients lose less blood under chloroform than under ether—a point of great importance in certain subjects. For patients over fifty-five years of age, and for very obese subjects, the C.E. mixture gives good results. As in abdominal surgery, there is greater liability to reflex circulatory shock under chloroform than under ether; but such shock in mammary surgery is in a sense conservative, for it limits hæmorrhage. When it begins to show itself, the depth of anæsthesia should be lessened, and in severe cases the C.E. mixture substituted for chloroform. In cases of slight shock it is best to do nothing more than reduce the depth of anæsthesia. The anæsthetist should see that the patient's body is not more exposed than is absolutely necessary, and the room should be kept as warm as for an abdominal section.

Should the surgeon require the patient's shoulders raised, the head should be raised also. If this be not done the neck-extension with abducted arm may give rise to embarrassed breathing with laryngeal stridor, cyanosis, and other symptoms.

The asphyxial difficulties thus initiated may readily be mistaken for true surgical shock. They are in reality due to faulty **posture.** Reference will be made in the following chapter to certain posture-paralyses which may follow breast operations (p. 247).

H. OPERATIONS INVOLVING THE BRAIN OR SPINAL CORD

Patients about to be subjected to these operations are sometimes more or less **drowsy or comatose** at the time of administration; and the anæsthetist should therefore make himself thoroughly acquainted with the exact state of the patient before administering the anæsthetic (see p. 175). So far as the actual performance of the operation is concerned, the best results are undoubtedly obtained by the use of **chloroform.** The mixed narcosis of chloroform and morphine, which was for some time employed in these cases, is now rarely used (see Chap. XVI.). Should a preliminary injection of morphine have been given, the anæsthetist must administer chloroform very sparingly, and attempt to secure an analgesic rather than a true anæsthetic state. Should no morphine have been administered, deep anæsthesia may at first be necessary; but as the operation proceeds and as shock tends to increase, a lighter and lighter anæsthesia will be advisable. When intracranial pressure is abnormally high, respiration may cease during the induction of anæsthesia, and it may be necessary to relieve the tension before breathing can be re-established.[1]

The chief point concerning operations upon the spinal column and cord is that the prone or almost prone posture may introduce respiratory complications. In some cases, moreover, there may be no thoracic breathing; and the position of the thoracic viscera may be greatly altered by the spinal deformity. A variable degree of surgical shock is common in these operations. Generally speaking, deep anæsthesia should be avoided in the prone posture, and a careful watch kept upon respiration and circulation. The choice of anæsthetic must be regulated by the general circumstances of

[1] See a case reported by Dr. Percy Noble (*Lancet*, 28th April 1900, p. 1210). See also *Lancet*, 16th May 1903, p. 1367.

the case. Although chloroform may be preferable from the surgeon's point of view, the anæsthetist may find it advisable in bad cases to employ ether, either alone or in mixture with chloroform. Operations for spina bifida in infants are best performed under ether administered from a semi-open inhaler (p. 327).[1]

I. PARTURITION AND OBSTETRIC OPERATIONS

Of all the anæsthetics at present known, chloroform is the most suitable for administration during **natural labour.** It quickly produces an **analgesic** state without materially affecting uterine contractions. The patient passes into a dreamy condition, with rather deep respiration, and a pleasant feeling of numbness in the extremities. Speaking generally, chloroform should not be pushed beyond this point. It is not desirable to commence the administration until there is distinct evidence that true labour pains have begun. When the patient shows by her movements that a "pain" is approaching, chloroform should be applied; as little as possible given; and even before the "pain" has actually passed off the anæsthetic should be withdrawn. The patient should be allowed to recover completely from the analgesic effects of the drug between the "pains"; and in these periods food or stimulants may be taken. During the expulsion of the fœtus, Spiegelberg[2] recommends that consciousness should be allowed to return in order to lessen the risk of the perineum becoming ruptured. It is, however, at this particular juncture that pain is often most intense, so that many obstetricians humanely increase rather than diminish the depth of anæsthesia. Most authorities agree that if chloroform be given more deeply than is here suggested there is a risk not only of uterine inertia, and a prolongation of the labour ensuing, but of *post-partum* hæmorrhage, more especially in persons predisposed to this condition. **Chloroform should not be employed** when the uterine contractions are

[1] Just before going to press an Address by Sir Victor Horsley "On the Technique of Operations on the Central Nervous System" has appeared (see *Brit. Med. Journ.*, 25th Aug. 1906, p. 411). The remarks made on anæsthesia in this branch of surgery are of considerable interest.

[2] *A Text-Book of Midwifery* (New Syd. Soc.), vol. i. p. 268.

feeble, when small doses of the drug appear to retard labour,[1] or when any great respiratory difficulty is present.

When **true surgical anæsthesia** is required, as for turning, instrumental delivery, craniotomy, and other operations, ether should, as a general rule, be given. Though the use of chloroform in analgesic doses during labour may be said to be free from risk, there is no reason to suppose that when this anæsthetic is pushed to its fullest degree this almost absolute immunity from danger is to be relied upon.[2] But seeing that chloroform has been very largely used for obstetric operations requiring deep anæsthesia, and that very few fatalities have occurred, it would seem that there must be some explanation of this freedom from accident. When fatalities under this anæsthetic have occurred in surgical practice at the very outset of the inhalation, *i.e.* before consciousness has been lost, the factors of fright and apprehension have possibly been at work. These factors are, as a rule, wholly absent when chloroform is given to relieve the pains of labour. The patient is occupied with her suffering, and the prospect of speedy relief from pain gives rise to a feeling of comfort rather than to one of alarm. The view that the physiological hypertrophy of the heart enables this organ to cope with any undue strain which may be imposed upon it is probably quite erroneous. A very large proportion of those who have succumbed under chloroform have had healthy and vigorous hearts. Moreover, the clinical fact is established beyond doubt that, in surgical practice, the best subjects for chloroform are those whose general vital functions are somewhat impaired by illness. In the comparatively few cases in which the author has administered chloroform to its full extent during or immediately after labour, the patients have certainly taken this anæsthetic remarkably well. There has apparently been a fuller and better circulation and respiration than in ordinary

[1] For further information I would refer the reader to Dr. Galabin's practical remarks. See *A Manual of Midwifery*, 2nd edition.

[2] It is a mistake to suppose that chloroform accidents during child-birth are unknown. See a fatal case, *Lancet*, 2nd Feb. 1889, p. 249. The administrator had given chloroform four hundred times before. See also an article by Dr. Ballantyne (*Scot. Med. and Surg. Journ.*, Jan. 1897), who has collected eight deaths during labour under chloroform.

cases. Dr. Lombe Atthill,[1] who has had forty years' experience with chloroform in obstetric practice, suggests the possibility of the safety being due to the fact that "in these cases the involuntary expulsive efforts seldom entirely cease, and as at the expiration of each of these, comparatively deep inspiration follows, it may tend to prevent asphyxia. . . ." Mr. A. H. Tubby[2] very aptly harmonises Dr. Atthill's clinical facts with recent physiological teaching. There can be no doubt that in many cases in which chloroform produces unsatisfactory effects, the difficulty seems to be one arising in the first instance from feeble or hampered respiratory movements, and consequently an inadequate pulmonary circulation. The deep respirations of labour would obviate this sluggish pulmonary circulation by emptying the right heart more efficiently. Dr. Galabin believes that the high abdominal pressure which is necessarily caused by the distension of pregnancy prevents that undue vaso-motor dilatation which might otherwise arise under chloroform.[3]

J. OPHTHALMIC OPERATIONS

There are special reasons why the maintenance of a perfectly tranquil anæsthesia during ophthalmic operations is a matter of comparative difficulty. In the first place, the head is usually adjusted face upwards and slightly extended; so that mucus and saliva tend to flow backwards and to induce reflex disturbances, whilst the tongue may obstruct breathing. Secondly, the depth of anæsthesia is liable to considerable fluctuations, by reason of the anæsthetist having to discontinue the administration from time to time, in order to meet the requirements of the surgeon. And thirdly, the eyes are often unavailable as guides. There have been a large number of chloroform fatalities in ophthalmic practice, and the explanation of the fact is probably to be found in these considerations. Ether is, in one sense, a more suitable anæsthetic than

[1] *Brit. Med. Journ.*, 16th Jan. 1892.

[2] *Brit. Med. Journ.*, 30th Jan. 1892.

[3] For further information see an interesting *résumé* of the whole subject by Mr. H. Bellamy Gardner (*Brit. Gynæcolog. Journ.*, May 1896). This author points out that there is no decided evidence to show that anæsthesia has any injurious influence on the fœtus.

chloroform, because the patient can be placed so deeply under its influence that inconvenient coughing, swallowing, straining, or vomiting may be prevented. The anæsthetic, whatever it may be, must be pushed freely. There are, of course, many cases in which, from the patient's age or general condition, the C.E. mixture or chloroform should be used, either in preference to ether or in succession to that anæsthetic. Thus, for iridectomy in elderly people, the C.E. mixture answers admirably. For strabismus operations in children, ether is unquestionably preferable to chloroform.[1] For the operation of enucleation the choice of the anæsthetic must depend upon the state of the patient.

K. OPERATIONS UPON THE EXTREMITIES

Complete **muscular flaccidity** is essential for the examination of stiff and painful joints, the reduction of dislocations, and the setting of fractures. Ether is the best anæsthetic for the reduction of dislocations of the shoulder: curiously enough, chloroform has proved particularly lethal during these operations.[2]

For orthopædic operations deep anæsthesia is also generally advisable. The legs and feet are particularly liable to move reflexly at the moment of operation. This is noticeably so in the case of nitrous oxide. Even if this anæsthetic be administered with oxygen till as deep an anæsthesia as possible is procured, there is almost invariably a reflex twitch when an

[1] Mr. Brudenell Carter, in a very able letter to the *Lancet* (7th August 1875, p. 227), strongly advocates the use of ether in preference to chloroform in ophthalmic practice, and refers to a surgeon who lost sixteen patients under chloroform administered for operations upon the eye.

[2] Lisfranc, Verneuil, Böckel, and Guillon have all drawn attention to this fact. They believe the fatalities to have arisen in consequence of the "unfavourable position of the patient" during the administration, by which they probably mean that respiration is likely to be interfered with during the necessary manipulations. We must remember, too, that complete relaxation is always essential—in other words, that the anæsthetic has to be pushed very freely; that the subjects of dislocated shoulder are often men who have met with the accident whilst under the influence of alcohol; that food is often present in the stomach when anæsthesia is induced; and lastly, that the administration is not unfrequently placed in unskilled hands. These facts, together with the suggestion made by the above observers, seem to the author to point to the necessity for considerable caution in administering chloroform for the reduction of a dislocated shoulder.

incision about the leg or foot is made. Ethyl chloride is useful in short cases.

L. OTHER OPERATIONS, PROCEDURES, OR CONDITIONS FOR WHICH ANÆSTHETICS MAY BE REQUIRED

General anæsthetics, and more particularly chloroform, are sometimes employed in **renal colic, biliary colic,** and **other acutely painful seizures.** In such cases the selected agent should be administered in analgesic rather than in anæsthetic doses, and, as when exhibiting chloroform in normal labour (p. 219), pain should be relieved without wholly destroying consciousness.

Chloroform has been extensively used in the treatment of **puerperal eclampsia.** In these cases it is necessary to push the administration somewhat more freely than when the mere relief of pain is desired. Dr. Galabin[1] makes the following practical remarks :—

"At first the patient may be brought pretty fully under the influence of the drug, but afterwards it may be given only from time to time and in partial degree. Any premonitory signs of a paroxysm, such as increased muscular restlessness, more rapid breathing, or contraction of the pupils, are indications for giving more of the chloroform, and so, *a fortiori*, is the recurrence of a fit. When chloroform is given judiciously, in this partial degree, the administration may be continued for hours together, without danger."

The late Dr. Playfair[2] pointed out that chloroform occasionally fails to control the paroxysms. The same author stated that the use of an anæsthetic is contra-indicated when the patient is cyanosed. Spiegelberg[3] refers to a case in which sudden death took place during the use of chloroform for puerperal eclampsia.

Chloroform quickly relieves the spasms of **strychnine poisoning.** In some of the recorded cases it was only necessary to give the drug in analgesic doses;[4] whilst in others deep

[1] *A Manual of Midwifery*, 2nd edition, p. 324.
[2] *Science and Practice of Midwifery*, vol. ii. 6th edition.
[3] *A Text-Book of Midwifery* (Sydenham Society). p. 220.
[4] *Brit. Med. Journ.*, 22nd April 1882, p. 575.

anæsthesia was produced.[1] In one case[2] chloroform was administered, almost without intermission, for seven hours.

In the treatment of **tetanus**, chloroform has also been found distinctly advantageous.[3] As in strychnine poisoning, muscular spasm subsides before true anæsthesia is reached; so that it is not necessary to push the chloroform very far. Sometimes a considerable interval of freedom from spasm may elapse after the inhalation, in which case no more of the anæsthetic need be given till the tetanic rigidity recommences. Should the spasms, however, be nearly continuous the administration may be maintained. One case is recorded in which a child was kept more or less under the influence of chloroform for thirteen consecutive days, 100 oz. being used. In extreme cases, in which there is intense spasm of the jaws, neck, thorax, and abdomen, it may be difficult or impossible to administer chloroform without intensifying the existing condition.[4]

[1] *Lancet*, vol. ii., 1875, p. 310. [2] *Ibid.*, vol. ii., 1867, p. 118.

[3] See *Braithwaite's Retrospect*, vol. ii., 1877, p. 59—"On the State of Therapeutics in Tetanus." See also *Medical Record*, 15th June 1879, p. 243; and *Lancet*, 31st July 1880, p. 171.

[4] A case occurred at the London Hospital in March 1899, in which several attempts were made to relax the tetanic spasm which was threatening the life of the patient by asphyxia. On each occasion the chloroform vapour, even though very carefully given, seemed to aggravate the condition, and artificial respiration became necessary in re-establishing breathing. Eventually, however, the tetanic spasm got the upper hand, and the patient died.

CHAPTER VIII

THE EXTRANEOUS CIRCUMSTANCES OF ANÆSTHETISATION

In order to ensure, as far as possible, successful anæsthetisation, it is essential that attention should be paid to numerous points prior to and during the actual administration.

Experience has shown that patients who have been subjected to the regime of a nursing home for a few days before a surgical operation, invariably pass into and out of general anæsthesia more smoothly than those who have been operated upon without any such preparation. Whenever practicable, therefore, it is important that attention should be paid to the diet, the state of the bowels, the avoidance of tobacco-smoking, etc., during the twenty-four or forty-eight hours immediately preceding a major surgical operation. Even in the case of so-called minor operations the patient should be prepared for anæsthetisation as far as circumstances will permit.

Some years ago, at a surgical home in London, the author anæsthetised a little boy on about sixty separate occasions, each time employing the nitrous oxide-ether-chloroform sequence. The operations necessitating the anæsthesia were in three batches, so to speak, separated by an interval of a few months. During these intervals the little patient went home. The operations themselves took place at intervals of a few days. After the first administration in each batch, *i.e.* soon after the patient had arrived in London, there was a good deal of nausea and vomiting; after the second administration the after-effects were less; after the third they were very trifling; and after the remaining administrations of the batch they were practically nil.

It is always advisable to have a third person in the room during the administration of an anæsthetic.

A. HOUR OF ADMINISTRATION: REGULATION OF DIET: ETC.

It is hardly necessary to point out that as patients are usually in a state of nervous tension before operations they should not be kept waiting a moment beyond the hour that has been arranged. Some considerate surgeons, indeed, make a practice of naming to the patient a somewhat later time than that actually fixed with their colleagues and nurses. By this simple device the suspense before an operation may be reduced to a minimum.

It is an accepted fact that the **early morning (8 9.30 a.m.)** is the best time for the administration of a general anæsthetic for a surgical operation. Putting exceptional cases aside, patients are brighter and fresher in the morning than in the after-part of the day. But the most important reason for choosing the time indicated is that the stomach is then generally empty and in a state of quiescence. Adult patients in good health may be allowed their usual meals the day before the operation, provided that nothing be taken after 7 or 8 P.M. A light and nutritious meal at or about 7 o'clock on the previous evening is generally to be recommended. The author has known patients who have had an exceptionally good dinner the night before the operation, and children who have eaten heartily of pudding before going to bed, to eject a considerable quantity of semi-digested food after the anæsthetic on the following morning. The practice of giving beef-tea, soup, tea, coffee, an egg beaten up in milk, or an egg with brandy during the night or early hours of the morning, is open to much objection. Digestion is not always as rapidly performed as is generally believed, and when nourishment is taken at unusual times, the process may be greatly retarded. Moreover, even though beef tea may have been given several hours beforehand, so that the stomach is empty at the time of the administration, considerable gastric irritability may remain as the result of recent digestion. Milk is particularly prejudicial. It requires such a length of time to become digested and to disappear from the stomach, and leaves the stomach so irritable

after it has disappeared, that it is, in the author's judgment, the worst of all forms of nourishment either before or after anæsthesia. The best results, so far as the avoidance of gastric disturbances during anæsthesia is concerned, are undoubtedly met with in cases in which nothing whatever has been taken since the previous evening.

When the operation cannot be arranged for the early morning, the next best time, so far as anæsthesia is concerned, is either about 1 P.M. or 2 P.M., or 5 P.M. or 6 P.M. Administrations conducted in the middle of the morning or in the middle of the afternoon, *e.g.* at about 11 A.M. or 3 P.M., are often unsatisfactory owing to the difficulty of regulating the diet for operations at these times.

As a general rule an **interval of five hours** should have elapsed between the last meal and the administration of a general anæsthetic for a surgical operation.

In the accompanying table will be found suitable dietaries for patients about to be operated upon at the hours specified :—

Operation.	Diet.
8 A.M. . 9 ,, . 10 ,, .	No food or drink since previous evening.
11 ,, . .	*If patient awake*, cup of tea or coffee (according to habit) with biscuit or toast, or cup of clear soup, not later than 6 A.M.
12 Noon . .	Cup of weak tea or coffee with biscuit or toast, or cup of clear soup, not later than 7 A.M.
1 P.M. . .	Tea, coffee, or clear soup, with toast, not later than 8 A.M.
2 ,, . .	Light fish breakfast before 8 A.M., or tea, coffee, or clear soup, with toast, before 9 A.M.
3 ,, . .	Light fish breakfast, or simply tea, coffee, or clear soup, with toast, before 9 A.M.
4 ,, . .	Tea or coffee with toast before 7 A.M., and cup of clear soup or broth at 11 A.M. ; or (better) fish breakfast at 10 A.M.
5 ,, . .	Tea or coffee with toast before 8 A.M., and cup of clear soup or broth at 12 noon.
6 ,, . .	Fish breakfast at 8 A.M., and cup of clear soup or broth at 1 P.M.

The author has never seen any difficulty attributable to too lengthy a fast; but he has frequently met with difficulties of a respiratory or circulatory character due either to the presence

of nourishment within the stomach or to an irritable state of that organ apparently dependent upon recent digestion.

The above rules can hardly be adhered to when we have to deal with **exhausted patients**, or with those who are liable to feel faint after a comparatively short abstinence from food or stimulants. Moreover, patients advanced in years should not be kept quite so long without food as younger persons; partly because they more readily show signs of exhaustion, and partly because they are far less liable than their juniors to after-nausea and vomiting. Generally speaking, exhausted and asthenic subjects who are to be operated upon in the early morning should be allowed some clear soup during the night; and in extreme cases a little wine, brandy, or whisky may at the same time be taken with advantage. Similar arrangements are indicated when the operation is fixed to take place during the day, *i.e.* some soup should be given about four hours before the administration. Milk, eggs, and ordinary beef-tea are not so suitable as clear soup.

As a general rule **alcohol** should not be given by the mouth before an anæsthetic, as it is liable to interfere with anæsthesia, and in some cases to cause vomiting during the administration.[1] Some writers, however, consider alcohol advantageous.[2]

Should the patient's **circulation** be **extremely feeble**, it is a good plan to give an enema of brandy and water, or brandy and beef-tea, a short time (twenty minutes or so) before the administration.

Although it is unnecessary in the case of nitrous oxide that the diet should be as strictly regulated as in the case of ether or chloroform, it is important that some attention should be paid to this point. When the gas is administered in its pure state, an interval of three hours after the last meal is advisable, although it is exceedingly common for patients who have quite recently taken food to pass through this form of

[1] In one case, in which a patient had taken some champagne two hours before an administration of nitrous oxide and ether for a dental operation, hesitating breathing, masseteric spasm, coarse moist laryngeal sounds, and other inconvenient symptoms arose, and caused delay and difficulty.

[2] See Clover, *Brit. Med. Journ.*, 14th February 1874. See also an interesting letter "On the Value of Alcohol before Chloroform" (*Brit. Med. Journ.*, 20th July 1889). Also *Asclepiad*, January 1892.

anæsthesia without vomiting. But when nitrous oxide is to be given with oxygen, even for a brief operation, the diet must be carefully regulated, in accordance with the foregoing principles. The same may be said when one administration of pure nitrous oxide is to be immediately followed by another, or when this gas is to be given with air for a lengthy operation.

Patients about to be anæsthetised should be requested to abstain from **smoking** for several hours beforehand. Excessive smokers who are about to undergo operations of some duration, or operations in which throat irritability might be inconvenient, should be requested not to smoke for at least two or three days before the administration.

B. STATE OF THE BOWELS AND BLADDER

In ordinary surgical cases, the best plan appears to be to give a purgative the night but one before the operation, and an enema on the morning of the operation. If a purgative be given the night before the operation, inconvenience may arise during, or immediately after, the administration. Care should be taken to select purgatives appropriate to the case. The author has on one or two occasions satisfied himself that certain symptoms of depression [1] which have arisen, during or after the use of an anæsthetic, have been wholly or partly dependent upon the violent purgation to which a somewhat feeble patient has been subjected. There are, of course, certain cases in which the use of strong measures is highly desirable. The so-called "bilious" subjects, those who are generally constipated, and young people (particularly boys) of gluttonous habits, must be freely purged, otherwise after-vomiting will be likely to be troublesome.

The bladder should invariably be emptied before anæsthesia is induced. This rule is particularly necessary in the case of children who are about to be anæsthetised by nitrous oxide free from oxygen, for during the clonic muscular movements micturition is liable to arise.

[1] Snow believed that free purgation the night before a rectal operation was likely to induce syncope during anæsthesia; and he met with cases which appeared to render this view extremely probable. See Snow, *op. cit.* p. 104.

C. CERTAIN SPECIAL PREPARATIONS

In such operations as those for fæcal fistula, it may be necessary to employ **rectal feeding** for one or two days beforehand.

Some surgeons **wash out the stomach** prior to abdominal section for intestinal obstruction, pyloric or duodenal disease, etc. (pp. 174, 206, and 213).

In cases of extreme exhaustion, nutrient and stimulant enemata, the subcutaneous use of **strychnine**, or even the **intravenous injection** of **saline fluid** may be indicated.

The employment of **morphine** in association with general anæsthetics is specially dealt with in Chapter XVI.

The preliminary application of **cocaine**, in the form of spray, to the nose and throat, has been recommended, partly with the object of preventing or lessening the cough, holding of breath, and irritation often produced by ether and chloroform, and partly with the object of averting the early reflex syncope which such irritation is supposed to occasionally induce (p. 126). Rosenberg[1] originally proposed this method; and it has been thoroughly tested by Gerster,[2] Mayer, and Theobald of New York. Whilst there can be no doubt that the irritant effects of anæsthetic vapours may be to a great extent thus averted, experience has shown that the plan is not without its objections, and that symptoms of cocaine poisoning may readily be induced. Moreover, as there are at our disposal numerous methods of administration by which all initial pungency of vapour may be avoided, there is no necessity to resort to this cocainisation of the upper air-tract.

The use of **atropine** before chloroform has its advocates.[3] As we shall see, however, when discussing chloroform anæsthesia, it is questionable whether this precautionary measure has any advantage in actual practice.

The use of **cocaine and adrenalin** locally is advantageous before certain intra-nasal and intra-laryngeal operations, causing diminution both of hæmorrhage and of laryngeal sensibility.

1 See *Berliner klinische Wochenschrift*, Nos. 1 and 2, 1895.
2 See *Annals of Surgery*, January 1896.
3 See *Trans. Roy. Soc. of Edin.*, vol. xli. Part II. (No. 12).

Patients suffering from **acetonuria** or "**acid intoxication**" (p. 174) require special treatment before anæsthetisation. When circumstances permit, bicarbonate of soda in appropriate doses should be administered for some days before the operation, and the action of the bowels, kidneys, and skin encouraged. In urgent cases there may be little or no time in which to bring the patient under the influence of alkalies; but an attempt should be made whenever practicable.

Lastly, in certain highly excitable subjects the preliminary administration of **bromide of potassium** may be useful (see Illustration Case, No. 35, p. 516).

D. INSPECTION AND EXAMINATION OF THE PATIENT

Whenever practicable the patient should be inspected and examined before the administration. Bearing in mind the fact that the phenomena of surgical anæsthesia are largely dependent upon age, temperament, physique, habits of life, quantity and quality of blood, the state of the respiration, the state of the circulation, and other factors (Chap. VI.), we cannot fail to recognise the advantages of ascertaining, as far as circumstances will permit, the general condition of the patient entrusted to our care. Information of value may often be obtained from the patient's usual medical attendant. Every one who has largely administered anæsthetics must be able to call to mind cases which would certainly have gone more smoothly had some particular pre-existing peculiarity or morbid state been recognised before the administration. Aortic disease, mitral stenosis, an extremely slow cardiac action, or emphysema may, for example, be easily overlooked unless care be taken. By considering the condition of the patient, we not only place ourselves in a better position to decide what anæsthetic or anæsthetic mixture should be chosen, but we are often able to anticipate, and possibly to prevent the occurrence of important symptoms during the administration.

A great deal of valuable information, both positive and negative, is afforded by the **general appearance and bearing of the patient.** Let us in a few words consider what may be learnt by simply observing the individual before us. Should

he walk to the operating table, couch, or chair, his mode of progression may afford us information. We shall notice whether he moves actively, or whether with considerable hesitation or difficulty. The exertion may be followed by breathlessness. Should the patient be partially or wholly recumbent when we are called upon to anæsthetise him, the precise position in which he lies may afford us information. If propped up we may note the number of pillows he requires. Those who suffer from chronic bronchitis, emphysema, other affections of the air-passages, or extreme abdominal distension, almost invariably insist upon being propped up to a greater or less degree. Marked dyspnœa will attract attention, and should be regarded as a very important symptom. Patients suffering from unilateral pulmonary or pleural affections will probably be found lying upon the diseased side. The presence of pain, however, may necessitate a precisely opposite position. Whilst observing and drawing our inferences from the walk or posture of the patient, we are able, as a rule, to roughly estimate his age. It must be remembered that the anæsthetist is concerned as much with the apparent as with the real age of his patient. The temperament, too, which plays an important part in determining the manner in which an anæsthetic is taken, usually shows itself on these occasions. This is more particularly the case with hysteria. It must be remembered, however, that women who are liable to outbursts of hysteria sometimes conceal their want of control so cleverly that the observer is deceived. The overworked and the highly-strung patient will be recognised, and should be treated with the utmost gentleness and care. Previous excesses in alcohol, as a rule, present little or no difficulty in their detection. The teeth and breath of the habitual smoker will foreshadow the occurrence of certain difficulties to which reference has already been made. The general physique of the patient will be observed. Gross, flabby individuals, with a large abdomen, muddy complexion, and double chin, will probably not be easy subjects to manage. Nor may florid, muscular young men, who live outdoor lives and enjoy excellent health, be the easiest subjects. Persons afflicted with extreme obesity will require careful management. On the other hand, patients of slim

build, who are more or less anæmic in appearance, generally give no trouble. Florid and more especially dusky-looking and congested patients will show cyanosis under nitrous oxide or ether—in fact under any anæsthetic, if air be withheld even to a slight degree. The pallor of true anæmia is readily recognised. Apart, however, from this pallor, we must remember that very nervous and apprehensive subjects may be much paler than usual at the time of administration. Their pallor disappears when anæsthesia is established; and, to the surprise of the anæsthetist, to whom the patient may be a stranger, they assume a florid colour.

The manner in which **respiration** is performed is specially important, and the reader is referred to preceding remarks upon this subject (p. 164). So-called "nasal" intonation generally indicates an inadequate nasal air-way, and this, as we have seen, is one of the most frequent causes of difficulties in anæsthetisation. The patient should be asked to close the lips and breathe through the nose; to take a deep breath through the mouth; and to give a cough. By these simple procedures it will be possible to estimate the calibre of the nasal channels; to gauge the freedom of lung expansion; to judge whether breathing is principally thoracic or abdominal; and to ascertain the presence or absence of many laryngeal, tracheal, bronchial, or pulmonary affections. An obstructed nasal air-way may call for the preliminary insertion of a mouth-prop; good thoracic expansion with no pathological character in the cough may permit of the use of the usual nitrous oxide-ether sequence; the characteristic cough of chronic bronchial catarrh with little or no secretion may at once point to the C.E. mixture as the best anæsthetic for a short operation; whilst the presence of stridor on deep breathing or of a moist cough may at once indicate that chloroform is the only permissible anæsthetic. The causation of dyspnœa or orthopnœa, particularly if associated with even slight cyanosis, should be most carefully investigated (p. 166).

The state of the **circulation** should be observed. It is always advisable to stethoscopically examine the heart; to feel both radial pulses; and to ascertain the cause of any notable pallor or duskiness. Feebleness, irregularity, intermittency, or

marked slowness of pulse should lead to further inquiry, in order that the most appropriate anæsthetic may be chosen. It is not uncommon, on first applying the stethoscope to the cardiac area of a patient whose heart's action is disturbed by nervous apprehension, to hear a bruit which subsequently disappears, and which is generally regarded as dependent upon a disturbed and irregular action of the chordæ tendineæ.

The **oral cavity should be inspected. Artificial teeth,** even though firmly fixed and apparently safe, should always be removed. Careful note should be made of loose natural teeth, lest they become dislodged during anæsthesia, either by jaw spasm, by the insertion of a gag, or by wiping out the mouth. A "quid" of tobacco has been known to lead to asphyxial symptoms during anæsthesia. In the case of children, sweetmeats may possibly be present in the mouth at the time of administration.

E. ATMOSPHERIC CONDITIONS : TEMPERATURE OF ROOM : CLOTHING : MAINTENANCE OF BODILY HEAT

As already pointed out (p. 48) the absorption and elimination of vapours and gases by the blood are directly influenced by the tensions of such gases and vapours within the lungs, so that the **barometric pressure** at the time of administration may be an important factor in anæsthetisation. The best illustration of this is afforded by Paul Bert's system of administering nitrous oxide and oxygen (p. 303). By this system atmospheric pressure is artificially raised and the effects of the anæsthetic are intensified. Although we have no observations bearing upon the point we should expect to find similar effects from anæsthetics when administered at levels considerably below the earth's surface. On the other hand, anæsthetisation at high altitudes, particularly by gases such as nitrous oxide and by very volatile liquids such as ethyl chloride and ether, might be attended by delay and difficulty, owing to the tension of such gases or vapours within the blood being too low to produce those results to which we are accustomed at lower levels. With an anæsthetic such as chloroform, however,

the vapour of which is dangerous in proportion to its concentration, the low barometric pressure of mountain heights would tend to lessen the chance of overdosage. Whether the fluctuations in barometric pressure which are constantly occurring at or about sea-level are ever sufficient to materially modify the usual phenomena of anæsthesia is questionable. Some observers maintain that such modifications may be observed in the case of nitrous oxide; but the facts which they bring forward to support this contention are not very conclusive.

See a paper by Mr. Bellamy Gardner: *Trans. Odont. Soc.*, Feb. 1904. Mr. Bellamy Gardner believes that with low barometric pressures, such as occasionally occur under ordinary circumstances, nitrous oxide produces a shorter and less satisfactory anæsthesia than usual. But the observations upon which he bases his conclusions hardly seem to warrant his deductions. The author has administered nitrous oxide and oxygen to the same patient, in the same way, on two occasions, separated by an interval of forty-eight hours, the difference in barometric pressure on the two occasions being 1·2 ins. He was unable to detect the slightest difference in the phenomena. One must bear in mind that with high barometric pressure and other favourable atmospheric conditions, the patient's general state of mind and body is more likely to be favourable to good anæsthesia than that state which obtains under opposite circumstances.

The **temperature of the air** during the administration of volatile anæsthetics may influence the results obtained, a high temperature being favourable to vaporisation and to subsequent elimination, whilst a low temperature will have an opposite influence. When the temperature is very low, delay and difficulty in anæsthetisation may be anticipated.[1] Again, according to the late Sir B. W. Richardson,[2] a very moist atmosphere may also interfere with absorption and elimination, whatever the temperature may be. This observer believed that when the air was surcharged with aqueous vapour, syncopal attacks under chloroform were particularly liable to be fatal, and that pulmonary œdema was more likely to result than if the air were dry. Patients certainly seem to take

[1] In the *Dental Cosmos* of 1869, p. 659, a case is related in which chloroform anæsthesia could not be induced when the temperature of the room was at 45° Fahr., whereas, on a subsequent occasion, when the temperature was 70° Fahr., the same patient was successfully anæsthetised. The author has met with a somewhat similar case.

[2] *Asclepiad*, 1892.

anæsthetics better when the weather is warm, dry, and bright than when opposite conditions prevail; but we must not forget that catarrhal affections of the nasal, pharyngeal, and laryngeal channels are much more common in cold damp weather, and that these affections, even though slight, may introduce difficulties into the administration (p. 165).

Whenever practicable the room in which the administration is conducted should be from **65° to 70° Fahr.** It should be ventilated, but free from draughts, and unless the weather be very warm, a fire should be burning.

The special disadvantages of administering chloroform in small rooms heated or lighted by gas or oil lamps have already been considered (p. 33).

Patients who are about to inhale an anæsthetic, whatever that anæsthetic may be, should invariably be **loosely but warmly attired.** Corsets, waist-bands, and collars should be unfastened. If the waist be constricted during the administration of nitrous oxide or nitrous oxide and oxygen, residual air will not be as rapidly expelled as under other circumstances, and imperfect anæsthesia will result. Loose clothing is not only advisable because it allows respiration to take place freely, but because it admits of the immediate application of restorative measures should these become necessary.

In all cases requiring a more or less protracted anæsthesia, the **maintenance of bodily heat** is of great importance. Under ether and chloroform the temperature invariably falls, sometimes to a considerable extent, and it is the duty of the anæsthetist to do his best to counteract this fall. Patients are often unnecessarily exposed during surgical operations, and this exposure is, in some cases, partly accountable for shock during or after anæsthesia. Feeble persons, infants, and those advanced in years require special care. Whenever possible, patients about to undergo severe operations should wear warm and thick underclothing and stockings, and be loosely covered with blankets previously warmed at the fire. In certain cases it may be advisable to previously warm the operating table by means of hot-water bottles, or a special hot-water bed or table may be used. Such precautions are strongly called for in anæsthetising infants for comparatively serious

operations, such as that for spina bifida, etc. It is often a good plan, in young or feeble subjects who are about to undergo formidable operations, to envelop the trunk and extremities in **cotton wool**, except at the site of operation. The plan of covering cutaneous areas with towels wrung out of antiseptic solutions is open to considerable objection.

Towards the close of lengthy operations, and in cases attended by shock, the bed to which the patient is to be transferred should be thoroughly warmed by means of **hot-water bottles**. These, however, should always be removed from between the sheets immediately before the patient is transferred. A large number of cases have occurred in which hot-water bottles have produced extensive burns during the unconsciousness of the recovery period.

F. POSTURE: CHANGE OF POSTURE: THE TRANSFERENCE OF UNCONSCIOUS PATIENTS: POSTURE-PARALYSES

Posture.—The posture of patients during general surgical anæsthesia is a matter of greater importance than is generally imagined. Many of the difficulties encountered by the inexperienced anæsthetist are referable, directly or indirectly, to this factor. A faulty posture may introduce undesirable complications into the anæsthesia; render the performance of a surgical operation difficult or even impossible; or lead to inconvenient or dangerous sequelæ. The chief postures now in use are shown in Fig. 11. Before commencing the administration an endeavour should be made to meet the wishes of the patient, as far as possible, in the matter of posture.

The **dorsal** posture is shown in Fig. 11 (A and B). In A the face is turned upwards; in B it is turned to the side. Posture B should be adopted whenever practicable for the induction of anæsthesia. The shoulders should rest upon the table and not upon a pillow; the head should be supported by one or two soft pillows, according to the depth of the chest, so that the head is in the body-line, being neither flexed nor extended. Flexion throws the base of the tongue against the pharynx and encourages stertor and obstructed breathing; extension deprives the larynx of its natural protector the epiglottis,

thus rendering swallowing difficult or impossible, and exposing the larynx to the entry of foreign substances. The face should be turned to one side; the hands with fingers intertwined should rest upon the chest. If the patient be touched or held by bystanders, excitement and struggling will be likely to take place. If, however, all the foregoing points be attended to and the nitrous oxide-ether sequence be employed (p. 479), the patient may usually be made to pass into deep anæsthesia without the hands becoming separated.

The **propped-up or semi-recumbent posture** is not shown in the figure. It is one of the worst positions from the anæsthetist's point of view, for mucus, saliva, vomited matters, blood, or other fluids that may be present within or about the fauces cannot be removed or permitted to escape by turning the head to one side. At the same time there are some patients who cannot breathe comfortably in other positions. This may be the case with the subjects of bronchial, pulmonary, or cardiac disease. Very obese patients, too, usually require several pillows. In all these cases the pillows may be successively removed as anæsthesia deepens, till the dorsal posture is reached. When the semi-recumbent posture is necessary by reason of the presence of ascitic fluid, the trunk should not be lowered till the fluid has been evacuated.

There is another posture which often causes difficulties during anæsthesia—that in which, by the adjustment of pillows, the **shoulders are raised whilst the head is extended.** Some surgeons employ this posture for such operations as cleft palate, excision of the tongue, thyroidectomy and removal of the breast. With some subjects little or no difficulty will arise, particularly if deep anæsthesia be practicable; but with so-called "bad subjects" such a posture may lead to considerable difficulties, and may even have to be altered during the operation. When this posture is required, the patient should first be anæsthetised in the usual position and then carefully moved into the new position. Most operators are gradually becoming aware of the disadvantages of this posture from the point of view of the anæsthetist, and except for certain cases in which it is essential it is now rarely used.

The **lateral posture** (Fig. 11 C) is perhaps the most

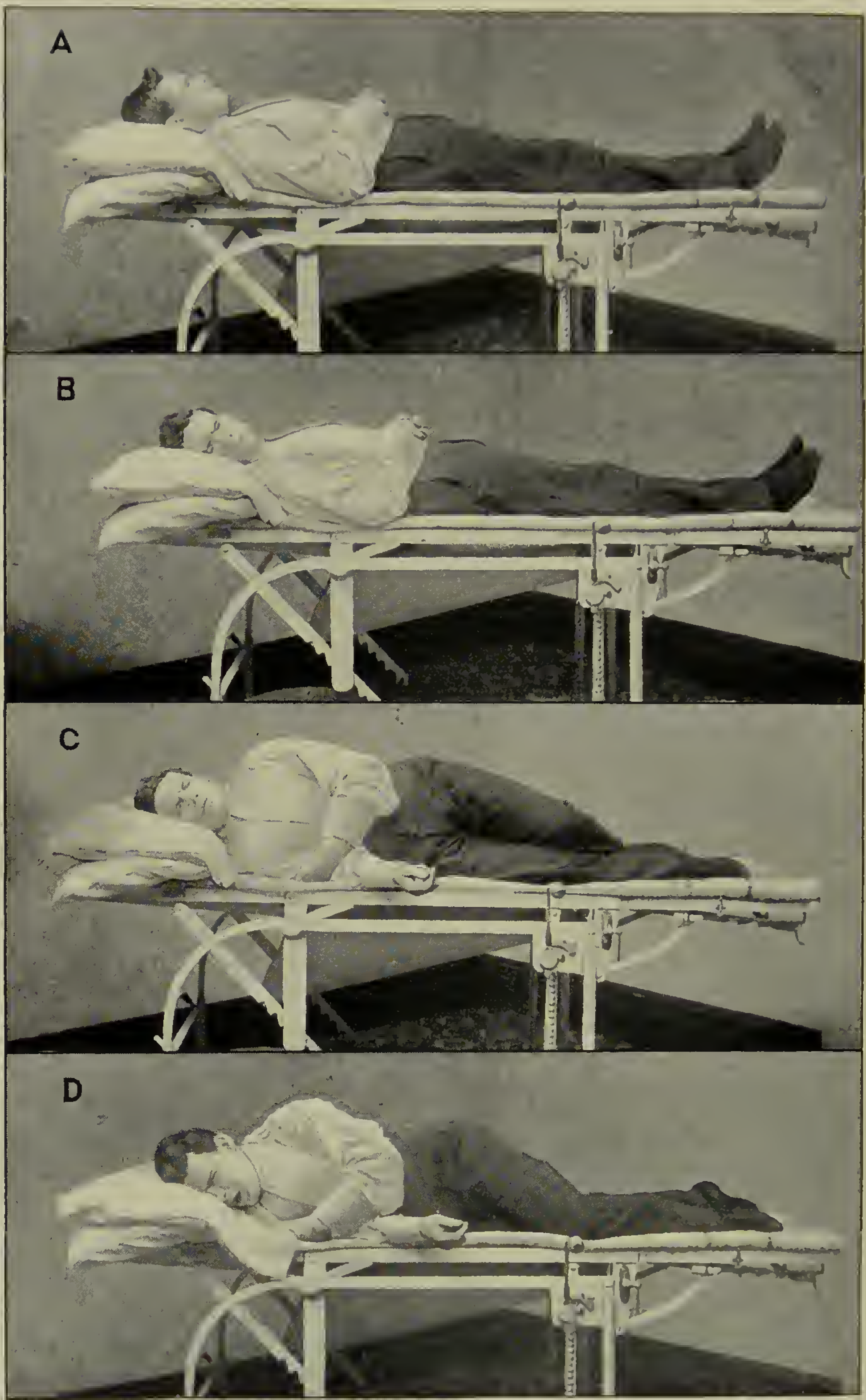


Fig. 11.—The Chief Surgical Postures. A, The Dorsal Posture: face looking upwards. B, The Dorsal Posture: face turned to one side. C, The Lateral Posture. D, The Latero-prone Posture. (Pages 238-39.)

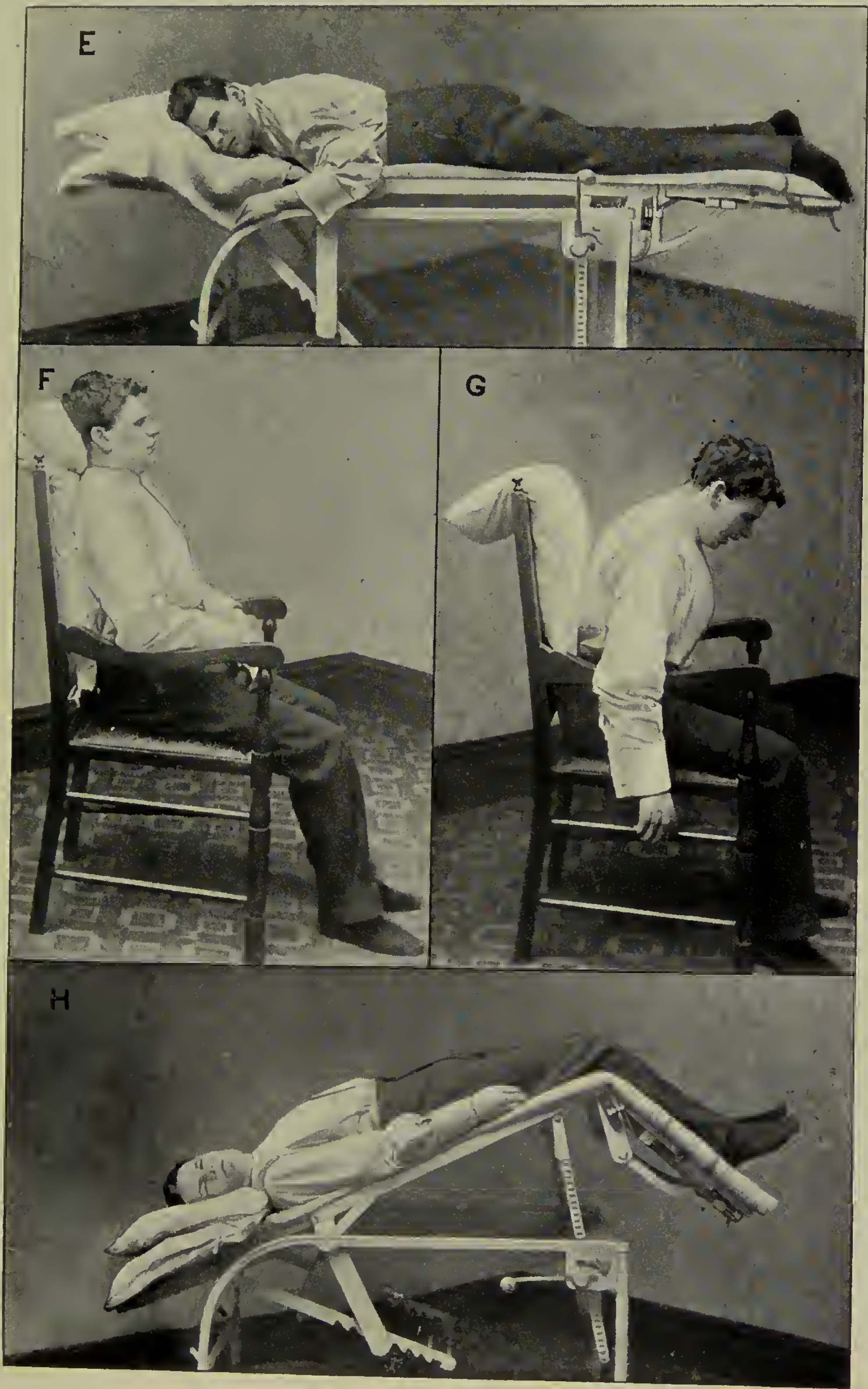


FIG. 11 (*continued*).—E, The Prone Posture. F, The Sitting Posture. G, The Bent-forward Posture. H, Trendelenburg's Posture. (Pages 238-39.)

advantageous of all, so far as the anæsthetist is concerned. It is the best posture when an anæsthetic has to be administered to a patient lying in bed. It is, *par excellence*, the posture for lengthy administrations of nitrous oxide and oxygen (Fig. 33, p. 314). We have seen, moreover, that for those operations within and about the mouth, throat, and nose that admit of performance whilst the patient is thus placed, it is the posture which is least likely to be associated with any respiratory embarrassment from the presence of blood (p. 185). An inclination towards the lateral posture, in other words the **dorso-lateral** posture, is often of advantage in inducing anæsthesia in routine practice. It may be secured upon the operating table by placing a pillow at the patient's back. Many patients prefer this to the purely dorsal posture of Fig. 11 (A and B).

The **latero-prone posture** (Fig. 11 D) is employed for many gynæcological, renal, and rectal operations. It is an excellent one, so far as the anæsthetist is concerned, for those operations within or about the mouth, nose and throat which admit of being performed with the patient thus placed; for all embarrassment to breathing from blood is avoided. When this posture is required, anæsthesia should be induced with the patient in the dorsal or lateral position, and when full anæsthesia has been secured, the change should be effected. It is important particularly in the case of heavily built and bronchitic subjects, that anæsthesia should not be too profound, otherwise the trunk weight may tell injuriously upon lung expansion (p. 551). Should the operation be of considerable length, the upper shoulder and arm should be supported by placing a pillow under the elbow; or Mr. Carter Braine's[1] ingenious arm-support may be used. Should respiratory embarrassment from imperfect lung

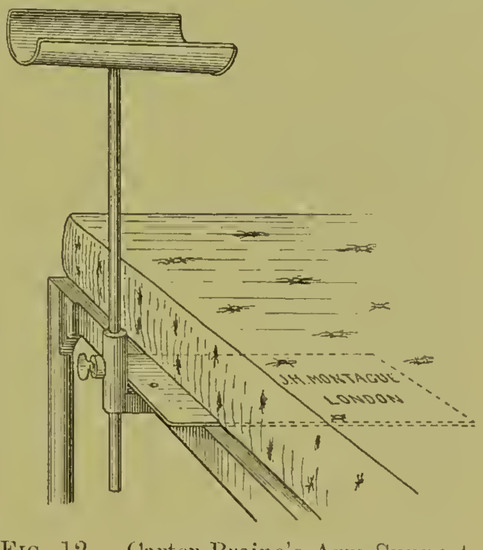


FIG. 12.—Carter Braine's Arm-Support.

[1] See *Brit. Med. Journ.*, 15th December 1900, p. 1716.

expansion persist for any length of time, it may induce a state of secondary circulatory depression which may easily be mistaken for true surgical shock. In some operations, as, for example, those upon the kidney, the two states—circulatory depression as the secondary result of the posture, and circulatory depression as the primary result of the operation—may coexist.

The remarks just made apply with even greater force to the purely **prone posture** (Fig. 11 E). When this posture is necessary, as it is for such operations as laminectomy, an endeavour should be made to provide, as far as possible, against respiratory embarrassment. By placing a sand-bag under each shoulder and one under each iliac spine, lung expansion will be facilitated. There is a modification of this posture which is used in Kraske's operation. The patient's trunk is prone; the pelvis is somewhat raised by pillows; the flexed thighs pass downwards over the end of the table; and the knees are supported by a chair. By a little adjustment the whole body may be placed somewhat obliquely, so that the head comes to the side of the table, thus rendering the administration less difficult. As mentioned below, the prone Trendelenburg posture may also be used in these cases.

The **sitting posture** (Fig. 11 F) has already been discussed when dealing with nose, throat, and dental operations (pp. 186 and 201), and the administration of chloroform to patients in this posture has been considered.[1] When the sitting posture is employed, it is easier to keep up a good type of chloroform anæsthesia if a small quantity of mucus or blood be present within the pharynx, than if the air-way be absolutely free. If therefore the proposed operation is to be a bloodless one, it is advisable to so adjust the preceding ether administration that mucus is somewhat freely secreted. If it be found impracticable to introduce into the administration this trifling but advantageous degree of obstruction, it may be necessary to stimulate respiration from time to time by sponging the

[1] Snow administered chloroform to 949 patients in the sitting posture and without any ill effects. He believed that, provided the ordinary means were adopted for the treatment of faintness, should it arise, there was no great objection to this position. He met with two or three cases, however, in which faintness came on in the sitting posture during recovery from chloroform.

fauces. In this way the patient will be prevented from passing into a state of inconveniently light anæsthesia, with pallor and diminished arterial pressure.

The "**bent-forward**" **posture** (Fig. 11 G) is sometimes employed when the naso-pharynx is to be cleared by means of the natural or artificial finger nail. The usual procedure is to anæsthetise the patient in the dorsal posture, to raise him to the sitting position, to insert a Mason's gag, and to tilt the whole body forwards. There is, however, little if anything to be gained by adopting this posture for throat operations.

The **Trendelenburg posture** is an exceedingly interesting one from many points of view (Fig. 11 H). The patient should be first anæsthetised in the dorsal position, and then placed as shown in the figure. As the pelvis is being raised, the head should be simultaneously lowered so as to keep the latter in the body-line. If the pelvis be raised without lowering the head, some degree of approximation of the chin towards the sternum will result. On the other hand, it is important that the occiput should not project and drop backwards over the end of the table, otherwise a state of extension will be produced. In either event respiratory difficulties might result. As shown in the figure, the head should be turned to one side. By the use of the Trendelenburg posture in abdominal surgery, the type of chloroform anæsthesia to which we are accustomed during abdominal operations upon horizontally placed patients becomes completely changed. We have already seen that when the patient is horizontal, these operations have a special tendency during deep chloroform anæsthesia to be attended by all degrees of circulatory shock. But if the patient be in the Trendelenburg posture, abdominal operations, even though performed during deep chloroform anæsthesia, are very rarely complicated by this condition. If the patient be horizontal the vessels of the splanchnic area which have become paralysed in the course of surgical shock retain their blood, with the result that the heart receives a diminishing quantity of this fluid, and is thus unable to adequately fill the arterial system. We thus meet with low arterial pressure, pallor, and in acute cases, respiratory feebleness or arrest from cerebral anæmia (p. 561). If, however, the patient be in the

Trendelenburg posture and respiration be unembarrassed, blood will not accumulate in the paralysed splanchnic vessels. It gravitates towards the heart; the arterial system is adequately filled; the colour is good; and respiration remains satisfactory, so far as the activity of the respiratory centres is concerned. Although the author has notes of a large number of cases of severe surgical shock in the horizontal posture, he has seen few, if any, in the Trendelenburg position. Another advantage of the position is that mucus and saliva tend to flow away from the laryngeal orifice, so that coughing and straining are uncommon. The chief disadvantage connected with the Trendelenburg position is that free respiration may become somewhat interfered with, particularly in certain subjects, not so much because the abdominal contents press unduly upon the diaphragm but because, by reason of the accumulation of blood within the veins of the more dependent parts, the tongue and adjacent structures have a tendency to increase in size, so that some degree of narrowing of the air-way results. It is not uncommon for the swollen tongue to protrude between the teeth, and for obstructive stertor to become audible. It may, in fact, be necessary to keep the lower jaw pressed well forwards in order to bring the engorged tongue away from the pharynx (p. 529). Should the patient be the subject of any condition attended by dyspnœa or likely to lead to dyspnœic symptoms during anæsthesia, the Trendelenburg posture is usually contraindicated owing to its favouring the accumulation of blood within the great veins and right heart, which accumulation, as we have seen, is such a prominent feature in most asphyxial states. By neglecting these considerations and by keeping a cyanotic and dyspnœic patient for some considerable time in the Trendelenburg posture, the face and scalp may become œdematous, and the wrist pulse feeble or imperceptible. The state thus brought about may be erroneously ascribed to surgical shock, but it is of a totally different nature. After the withdrawal of the anæsthetic and the removal of the patient to bed, there is, in a case of this kind a grave risk of fatal cardiac failure from the prolonged asphyxial strain to which the heart has been subjected. Owing to the fact that the circulation of deeply

chloroformed patients undergoing operations in the Trendelenburg posture is generally satisfactory there is little or no advantage in using ether when this posture is employed. It is possible, indeed, that the prolonged administration of ether to semi-inverted patients has its special disadvantages.[1] Care must be exercised in lowering patients from the Trendelenburg to the horizontal posture. Should the circulation be feeble and anæsthesia still deep, there is undoubtedly some risk of syncope occurring; but such syncope would probably be only temporary and easily treated.[2]

The author has on one occasion employed what may be termed the **prone-Trendelenburg posture** and with very good results. The operation was that known as Kraske's. When the patient had been fully anæsthetised, the operating table was arranged as shown in Fig. 11 H; the patient was carefully turned face downwards and adjusted so that the gluteal regions formed the highest part. The object of the posture was to limit the degree of surgical shock. The arrangement answered well, but further experience is necessary before a more definite pronouncement can be made concerning it.

The **lithotomy posture** is generally secured by the use of Clover's crutch. Anæsthesia should be induced with the patient in the dorsal posture, and full anæsthesia obtained

[1] The author has not had sufficient experience with ether in this posture to express an opinion. He has, however, through the courtesy and kindness of Mr. Meredith, the notes of a case which seem to him worthy of recording in this connection. A lady of thirty-eight was kept in a state of deep ether anæsthesia in the Trendelenburg posture for upwards of two hours. The operation was for a fibro-myoma. Recovery of consciousness was very prolonged and was accompanied by great restlessness. Fourteen hours after the operation the patient was only partially conscious. Aphasia and right hemiplegia were noted. An eminent physician, who saw the patient, diagnosed a small subcortical embolism. At the end of the first week speech began to return. Complete recovery both of speech and movement took place in about twelve months. It is quite possible that in this case the venous engorgement of the cerebral vessels due to prolonged etherisation in the Trendelenburg posture led to hemiplegia and aphasia either by extravasation or thrombosis.

[2] Cases have been recorded (*Lancet*, 30th December 1905, p. 1713) in which the lowering of the patient's body from the Trendelenburg to the horizontal posture is believed to have been responsible for subsequent intestinal obstruction. It is alleged that the sudden return of the abdominal contents towards the lower part of the abdomen has brought about an incarceration of the colon within the pelvis or a volvulus of the small bowel. Such allegations, however, must be received with caution. The author is informed by a leading obstetric physician that he has known fatal obstruction to arise a month after hysterectomy performed in the Trendelenburg posture, a coil of bowel having passed through a hole in the omentum presumably when the patient's body was lowered.

before the crutch is applied. In adjusting the crutch it is important that the leg straps should be placed some little distance *below* the knee. The neck strap is usually passed under one shoulder and over the other in order to interfere as little as possible with respiration. Very obese subjects and those who are plethoric and congested in aspect may evince such symptoms in this posture that its adoption may be impracticable. It is unadvisable, in the case of elderly patients with degenerated vessels, to maintain the lithotomy posture for any great length of time, owing to the risk of gangrene in the lower extremities.[1]

Change of Posture.—In certain cases a change of posture may prejudicially affect respiration; in others it may depress or even arrest the peripheral circulation. The subject may, therefore, be most appropriately considered from two points of view—the respiratory and the circulatory.

It is often necessary, particularly in rectal, gynæcological, renal, and abdominal surgery to place the patient in some posture other than that employed during the induction stage. Under these circumstances it is important that full anæsthesia be first secured before the change is effected, and that the breathing be carefully watched during the change. Respiratory embarrassment may readily arise if the posture be altered during induction, particularly in the case of muscular and obese subjects, whose upper air-passages are incapacious. The most probable explanation of this fact is that by moving the patient's body, mucus and saliva trickle or flow from one part of the upper air-tract to another, so that swallowing—the precursor of coughing, retching, and vomiting—is excited, and breathing becomes suspended. With this laryngeal closure from delayed or continuous deglutition there is often jaw-spasm and general rigidity. Cyanosis, with other asphyxial phenomena may thus quickly follow a change of posture during incipient anæsthesia. Moreover, in some subjects the simple handling of a limb during the induction stage, as in the application of a tourniquet or Clover's crutch, may reflexly suspend respira-

[1] A case has been verbally reported to the author in which this unfortunate accident occurred: but whether the gangrene resulted from the prolonged acute flexion of the popliteal artery or from the prolonged pressure of the leg-strap upon the vessels, he cannot say.

tion. If full anæsthesia be first secured, a change of posture will not, as a rule, embarrass breathing early in anæsthetisation. There are, however, certain short-necked, plethoric subjects who, even though they be deeply anæsthetised, cannot be moved from the dorsal into the lithotomy or into the Trendelenburg posture without a disconcerting degree of respiratory embarrassment taking place (p. 535). Towards the conclusion of an administration, change of posture rarely causes respiratory embarrassment of any importance. An illustrative case (p. 545), however, appears in a subsequent chapter, in which mucus was thrown by a sudden alteration of posture into an insensitive larynx and so caused arrested breathing.

Change of posture is not likely to prejudicially affect the circulation under ether even in profound narcosis. In the case of chloroform, however, a liability to syncope is incurred if a deeply anæsthetised patient be raised from the horizontal into the sitting posture. If it be necessary to effect such a change in posture, as in bandaging after breast operations, the patient should have shown some signs of recovery before the trunk is raised. Similarly, changes of posture should be very carefully effected when surgical shock is present. During this condition, raising the body from the horizontal into the sitting posture or from the Trendelenburg into the horizontal posture may be attended by syncope, unless the precaution has been taken of first allowing the patient to recover to a sufficient degree the vaso-motor control which has been in abeyance during deep anæsthesia.

Change of posture may be indicated as a remedial measure. Thus, if the circulation be greatly depressed, the substitution of the dorsal posture for the sitting or for the semi-recumbent, will produce marked improvement. Similarly, the substitution of the Trendelenburg posture for the dorsal may be followed by good results. Again, should respiratory embarrassment arise as the result of the latero-prone or prone posture, it may be necessary to place the patient, at all events temporarily, upon his side or back. Sometimes the dorsal posture should be changed to the lateral. This change is advisable as a routine practice after surgical operations in general (p. 596). It is

specially indicated, however, when blood or other fluids have entered the bronchial passages (p. 542).

The Transference of Unconscious Patients.—Speaking generally, the conveyance of unconscious patients from one spot to another is open to considerable objection, particularly in the early stages of anæsthesia. Whenever practicable it is advisable to anæsthetise the patient upon the table or bed to be used during the operation. The remarks already made as to the risks of change of posture during partial anæsthesia specially apply in the present connection. It may, in fact, be particularly hazardous [1] to move a patient from one place to another during the induction stage. In determining whether any given patient should or should not be moved, the most important consideration is the type to which he belongs. It is undesirable, for example, to carry from the bed to the operating table a heavily-built, thick-necked man, who is just becoming stertorous, unless indeed the bed and table be near one another, and a gag has been inserted in order to provide against arrested breathing. The same remark is applicable to the transference of other difficult or bad subjects, *e.g.* those with a distended abdomen who are about to be operated upon for intestinal obstruction, those with angina Ludovici, and those suffering from grave respiratory or circulatory affections. On the other hand, in the case of children, there is little or no objection to administering the anæsthetic whilst they lie in bed, and to transferring them when on the threshold of deep anæsthesia to the room prepared for the operation.

When, at the conclusion of an administration, it becomes necessary to transfer the still unconscious patient from the operating table or chair to bed, the transference may excite respiratory difficulties, similar in kind to, though less in degree than those which may arise during the induction stage. The practice of wheeling or carrying recovering patients from an

[1] See a case reported in the *Lancet* of 16th May 1903, p. 1368. The difficulties described came on immediately the patient was moved to the operating table. See also *Brit. Med. Journ.*, 22nd Oct. 1904, p. 1085, and *Lancet*, 17th Sept. 1904, p. 841, for details of a fatality apparently initiated by the transference of the patient to the operating table during partially established anæsthesia.

operating theatre or room to some other part of the building is not without its dangers. Fatalities have, in fact, taken place on these occasions. It will be convenient, however, to postpone further consideration of this point till we discuss the after-condition of the patient in the last chapter.

Posture-Paralyses.—It is important to bear in mind that when the extremities of anæsthetised patients have been fastened up or allowed to remain in certain positions for a considerable time, the nerve-roots or nerves themselves may be so stretched or compressed that paralytic states varying both in extent and in degree may result. Attention was first drawn to this point by Büdinger[1] in 1894; and Krumm,[2] Schwartz,[3] Weir,[4] Cotton and Allen[5] have contributed to our knowledge concerning it. By far the commonest posture-paralysis is one which is liable to occur after any prolonged operations during which the arm of the patient has been abducted and drawn upwards, whilst the head has been turned to the opposite side. The symptoms in such a case may exhibit great variety. An Erb's paralysis is very common, the deltoid, biceps, brachialis anticus, and supinator longus being affected. Defect in sensory power is also frequently observed. Recovery is often tardy, sensation returning before motion. As regards the immediate causation of the paralytic state brought about by the posture in question some difference of opinion exists. Some observers maintain that the brachial plexus becomes compressed between the clavicle and first rib; others that the compression takes place between the clavicle and the transverse process of the fifth, sixth, or seventh cervical vertebra; others that the plexus becomes stretched over the head of the humerus. Most observers agree that the turning of the head to the opposite side, by which the plexus is put upon the stretch, is an

[1] "Ueber Lähmungen nach Chloroform narkosen aus Billroth's Klinik" (*Archiv f. klin. Chir.*, Bd. 47, Heft 1); *Centralblatt f. Chirurgie*, 1894, xxi. 703-705.

[2] "Ueber Narkosen Lahmangen Sammlung," *Klinische Vorträge*, No. 139, 1895.

[3] "Des paralysies post-anesthésiques," *Congrès français de Chirurgie*, 1897, p. 688.

[4] *Medical News*, 1901, vol. lxxix. p. 124.

[5] *Boston Med. and Surgical Journ.*, 7th May 1903, p. 499, "Brachial paralyses —post narcotic."

important factor. This point is well exemplified in the following case, which occurred in the author's own practice before he was fully aware of the danger of the *combined* effect of fastening up the arm and turning the head to the opposite side. It is interesting to note that the paralysis took place in the arm which was *least* drawn upwards, showing that the turning of the head was, at all events in this case, quite as important a factor as the position of the arm.

Illustrative Case, No. 1.—F. 35: thin. Operation for appendicitis. Arms fastened up by means of a double wristlet connecting hands together at a distance of about 7 or 8 inches. Backs of wrists resting on pillow. *Right* arm pulled up more than left. Head turned to *right*. Administration lasted forty-eight minutes. On recovery of consciousness patient complained of inability to move *left* arm. Could not flex fingers. A few days later, tenderness was felt over cervical plexus above clavicle. This remained for a fortnight. Sixteen days after operation no noticeable improvement. Flattening below shoulder. No power of abducting arm. Grasp feeble, especially with first, second, and third fingers. Numbness over thumb and two and a half fingers. Pronation and supination slow and feeble. Nineteen days after operation she was seen by Dr. H. Lewis Jones, who reported as follows:—

"*Left upper limb.*—Weakness was present in the deltoid, the triceps, biceps, brachialis anticus, supinator longus, radial extensors of wrist, and extensor communis digitorum. The spinati appeared flattened, and the whole limb was thin. Voluntary power was very greatly reduced in all of these muscles, and was practically lost in biceps, brachialis anticus, and supinator longus. The flexors of the wrist and fingers, and the intrinsics of the hand were natural.

"There was a little impaired sensation of the dorsum of the hand.

"The electrical reactions were of normal quality everywhere, the muscles responding properly both to coil and to cells. No reaction of degeneration. In quantity or strength of reaction the response was weak."

Dr. Lewis Jones expressed the opinion that the injury was extensive in area, but slight in degree; that it had involved the fifth, sixth, and seventh cervical roots; that it was caused by a stretching of those roots; and that the stretching was partly due to the position of the arm during the operation, and partly to the position of the head and neck.

Another form of paralysis which is not uncommon is that which may arise from allowing the arm or arms of the patient to fall to the side of the operating table, so that the musculo-spiral nerve becomes compressed between the bone and the table edge. The prolonged application of straps and bandages.

e.g. a Clover's crutch or an Esmarch's bandage, may also induce temporary motor or sensory paralysis. Complete recovery from these various posture-paralyses generally takes place within a few weeks or months, though it may be delayed for as long as a year and a half. As regards treatment, Schwartz

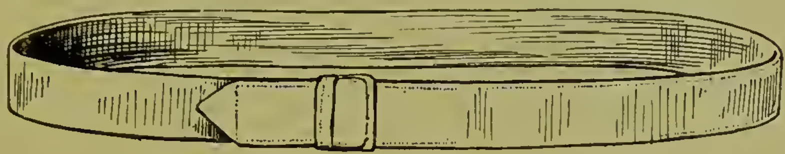


FIG. 13.—Band of webbing for fastening up arms.

recommends massage and electricity (continuous and intermittent). The symptoms generally clear up and disappear from the periphery towards the centre.

When full anæsthesia has been secured, it is important to see that the arms are safely adjusted. The best position for

FIG. 13A.—Band of webbing *in situ*.

them, as a general rule, is one of flexion, the hands resting below the clavicles. This position, which has the great advantage of rendering the radial pulse available for the anæsthetist, may be secured by pinning the sleeves or wrist-bands, by means of strong safety-pins, to the collar of the shirt or vest; or the arms may be adjusted by means of the simple band of webbing shown in Figs. 13 and 13A. Some

surgeons, in adjusting their patients for an abdominal section, prefer that the arms shall lie extended by the side of the patient. If it be necessary to abduct the arm and bring it upwards above the head, as in operations upon the breast and axilla, care must be taken not to do this too forcibly and, after what has been said above, it will be seen that the head should not be turned too much to the opposite side. The arms or legs should never be allowed to rest upon the table edge for any length of time.

G. THE EFFECTS OF SURGICAL PROCEDURES UPON ANÆSTHETISED PATIENTS: SURGICAL SHOCK: CONSECUTIVE OPERATIONS

It has been pointed out in preceding pages that surgical procedures are capable of very materially modifying what has been termed simple surgical anæsthesia (p. 41). It has been shown that the state with which we are familiar in the operating theatre is one which is frequently the product, so to speak, of the effects of anæsthetics on the one hand and of the proceedings of the surgeon on the other. Applying the terminology of Chapter III., we may say that surgical procedures often convert simple into complex anæsthesia. It is true that in many cases this complex condition hardly deserves its title, for beyond some slight alteration in breathing, pulse-rate, or colour, which would not have been observed had no surgical stimuli been applied, there may be nothing to distinguish it from simple or normal anæsthesia. But in many cases, and particularly in many abdominal, rectal, renal, and gynæcological cases, the proceedings of the surgeon have a more distinct share in the production of the symptoms presented by the patient, and the only reason why this fact is not more generally recognised is that we have become accustomed to look upon the stertor, the stridor, the pallor, and other phenomena of the operating theatre as necessarily due to the action of the anæsthetic or its method of administration.

It will now be convenient to attempt to bring to a clinical focus all that has been said in preceding pages as to the

effects of surgical procedures during anæsthesia, and to summarise the numerous ways in which these procedures may operate in practice. Surgical procedures may affect the anæsthetised patient:—

(i.) By causing hæmorrhage;

(ii.) By involving the exposure of large cutaneous or cut surfaces;

(iii.) By necessitating certain postures;

(iv.) By producing interesting but unimportant reflex effects upon the respiratory or circulatory system;

(v.) By producing such grave reflex respiratory or circulatory phenomena as to constitute surgical shock; or

(vi.) By the entry of air into veins.

(i.) The effects produced by **hæmorrhage** frequently modify the phenomena of anæsthesia. Blood may be lost gradually, as in Illustrative Case No. 70; or suddenly, as in Illustrative Case No. 69. Tachycardia, pallor, coldness of extremities, and pulselessness are the prominent symptoms of hæmorrhage. Infants, very old persons, and anæmic and cachectic subjects are naturally more seriously affected by loss of blood than more vigorous persons. During the removal of large and vascular tumours, the excision of the upper jaw, and similar cases, the anæsthetist should narrowly watch the colour and pulse of the patient. The greater the quantity of blood lost, the smaller should be the quantity of anæsthetic given. The effects produced by hæmorrhage may coexist with those of true surgical shock. In the above-mentioned Illustrative Cases the latter condition was absent. The symptoms produced by loss of blood differ from those of circulatory shock. In the former the pulse is usually quickened and little or no improvement takes place in the patient's condition as anæsthesia becomes lighter and the wound is closed. In surgical shock the pulse is usually slow and irregular, becoming quicker and better as the depth of anæsthesia lessens and the wound is sutured. Restlessness during the recovery stage is a common after-effect of severe hæmorrhage.

(ii.) The importance of maintaining the **bodily heat** during surgical operations has already been mentioned (p. 236). The exposure of large cutaneous surfaces to cold air or to towels

wrung out in lotions is certainly favourable to shock. The author has known general pallor and pulse feebleness to occur in a baby who was being anæsthetised by ether for circumcision, and who was lying without clothes close to an open window on a cold day. The prolonged exposure of large wounds, and particularly of the intestines or other abdominal contents, is also greatly to be deprecated as favouring, if not actually producing circulatory shock.

(iii.) The influences of **posture** have already been considered, and the reader who is interested in the effects of surgical procedures during anæsthesia will do well to carefully study the remarks already made on this subject (p. 237). It has been pointed out that certain postures are capable of interfering with respiration; whilst others may affect the circulation. The most important point, perhaps, in this connection is that if the respiratory embarrassment which may thus be brought about be allowed to persist for a considerable time, circulatory depression will become a conspicuous feature of the case. In this way a condition may arise capable of completely misleading the inexperienced anæsthetist, the pallor and feeble or imperceptible pulse being erroneously attributed either to the anæsthetic or to surgical shock. The diagnosis is at once settled by remedying the posture.

(iv.) It is unnecessary again to refer to the interesting but unimportant **reflex respiratory and circulatory phenomena** which may arise during anæsthesia. These have already been fully considered when dealing with the physiology of anæsthesia (pp. 73 and 75).

(v.) **Surgical shock** has already been defined (Chap. III. p. 44); and its three forms (*a*) respiratory shock, (*b*) circulatory shock, and (*c*) composite shock have been described.

Respiratory shock has been physiologically and clinically considered (p. 74). It has been shown to be the state which results when respiratory embarrassment of a threatening character is reflexly initiated by some surgical procedure. It occurs under all anæsthetics. A good example of this condition is furnished by Illustrative Case No. 42 (p. 536), which is worthy of careful study. It has been seen that this form of shock is most common during moderate anæsthesia, and that

the stertor, stridor, and muscular spasm which may individually or collectively initiate it are most frequently met with during certain operations. It is also clear, from what has already been said, that patients who, from natural or pathological causes, are most liable to respiratory embarrassment will be most liable to this form of shock. The commencement of operations, and particularly the commencement of rectal, gynæcological, and urethral operations, before full anæsthesia has been secured is liable to induce respiratory shock. The rapidity with which the circulation will fail in the course of this variety of shock will depend upon the special circumstances present (p. 570).

By far the commonest form of surgical shock met with in practice is that to which the term **circulatory** is applied in these pages (p. 76). Reflex circulatory disturbances are often altogether overlooked, or if observed are erroneously ascribed to other causes than the surgical procedure. The most interesting and important fact in connection with this form of shock is that, unlike respiratory shock, it is rarely if ever met with during light anæsthesia. It is essentially a phenomenon of full narcosis, and is, as we have seen, far more common under chloroform and its mixtures than under ether. There is still a widespread belief that a circulatory form of surgical shock may accompany the commencement of an operation during light or moderate anæsthesia, but this view should be discarded. The risk of operating during partially established anæsthesia is that of the reflex respiratory derangement above described. The author has no hesitation in asserting that in a very large number of the cases in which chloroform anæsthesia is believed to have been carried to the point of syncope, the surgical procedure has itself been the immediate and exciting cause of that syncope. In one sense and in one sense only is the anæsthetic blameworthy in the class of cases now under consideration—it predisposes to circulatory shock. When chloroform administration is carried to the point at which the corneal reflexes vanish, the cardio-vascular system relaxes, and the fall of blood pressure is considerable, reflex cardio-inhibitory and vaso-motor effects which would be hardly noticeable with a less depressant anæsthetic, or with a less

deep chloroform anæsthesia, now produce marked effects. In the absence of stimuli capable of reflexly affecting the centres in question, deep chloroform anæsthesia may usually be maintained without any sudden or alarming pulse depression. In the absence of deep narcosis under chloroform, surgical stimuli will not produce any noticeable circulatory effects. The two conditions, the narcotic or predisposing and the operative or exciting, must be present; and the result will be circulatory shock. This condition may often be studied during appendicectomy and other abdominal operations. The reader is therefore referred to Illustrative Cases Nos. 54 (p. 577), 56 (p. 578), and 59 (p. 580), in which will be found some striking examples of reflex circulatory shock. The diagnosis and treatment of the condition will be considered in connection with these Illustrative Cases (Chap. XIX. p. 587).

There is an interesting aspect of circulatory shock to which attention is not often directed. It is frequently, in a sense, a beneficial and conservative process, preventing undue hæmorrhage and rendering profound anæsthesia unnecessary. Experimental and clinical experience show that although it may assume alarming proportions, circulatory shock is very rarely fatal. A certain degree of it in an operation in which hæmorrhage might be prejudicial to the patient may often be allowed to display itself without calling for special treatment.

When respiratory shock is rapidly followed by circulatory depression, or when circulatory shock is rapidly followed by respiratory depression, the state to which the term **composite shock** has been applied will arise. For remarks upon this form of shock the reader is referred to Chapter III. (p. 78) and Chapters XVIII. and XIX. (pp. 537 and 576).

(vi.) The effects produced upon the anæsthetised subject by the **entry of air into veins** are considered on page 587.

Consecutive Operations.—Reference has already been made (p. 72) to the effects which may be produced upon the anæsthetised subject by the commencement of a second operation at the conclusion of the first. The degree of anæsthesia appropriate towards the close of one surgical procedure may be inappropriate for the commencement of another. If the second

operation be begun by a skin incision, it will usually be necessary to increase the degree of anæsthesia before the incision is made, otherwise inconvenient reflex results may occur. On the other hand, if at the conclusion of a lengthy operation the surgeon wish to remove tonsils or post-nasal adenoid growths, it is important that the patient should have regained his coughing and swallowing reflexes before the second operation is begun. If this point be not attended to, the larynx may readily become invaded by blood.

H. ARRANGEMENT OF APPARATUS: APPLIANCES AND REMEDIES WHICH SHOULD BE AT HAND DURING THE ADMINISTRATION

Whenever practicable, the apparatus to be used for the administration should be arranged before the patient enters the room in which the operation is to be performed. Everything should be in perfect working order. If the nitrous oxide-ether sequence is to be employed, the nitrous oxide bag should be filled to the requisite degree (p. 479), and in cold weather the ether chamber well warmed. Special attention must be paid to the valves of the nitrous oxide stop-cock. There should be no smell of anæsthetic vapour. Any gags, mouth-props, nasal tubes, etc., that will be required for a throat or jaw operation, should be sterilised and placed on a convenient table. The apparatus when ready may be covered with a clean towel. In ordinary surgical practice these arrangements may with advantage be made immediately before inspecting the patient. In this way the mental tension which often precedes an operation is reduced as much as possible.

The administrator should always have at hand:

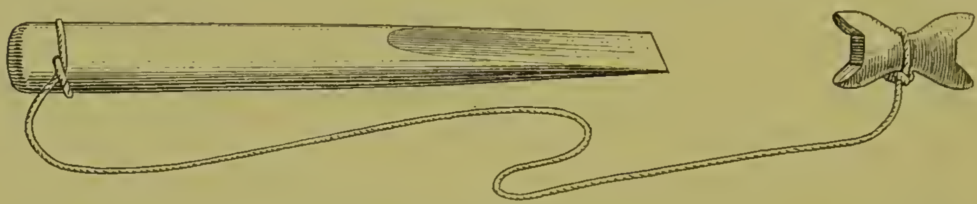
1. Instruments for opening the mouth and maintaining it in that position;
2. A pair of tongue-forceps;
3. A small basin, a towel, and a piece of sponge; and
4. Instruments for performing tracheotomy.

He ought always to be prepared to open the mouth of the patient without delay. There are some forms of respiratory embarrassment which can only thus be relieved. When the

teeth are more or less deficient, all that is necessary is to introduce a **Mason's gag.** The gag shown in Fig. 14 is, in the author's judgment, the best. The spring should be strong, so that the blades come closely together, and the notches for the

FIG. 14.—Mason's Gag ($\frac{1}{2}$ scale).

movable catch must not be too deeply cut. The parts of the gag which come in contact with the teeth or gums should be covered with rubber tubing. If there be any difficulty in introducing this gag, which is not unfrequently the case in



FIGS. 15, 16.—Wooden Wedge for separating clenched teeth, and Mouth-Prop for keeping teeth apart.

muscular subjects with good teeth, some form of **mouth-opener** must be used. The wooden wedge of Fig. 15 answers well. A small strong **mouth-prop,** so made that it cannot slip when placed between the front teeth (Fig. 16), is often of use either

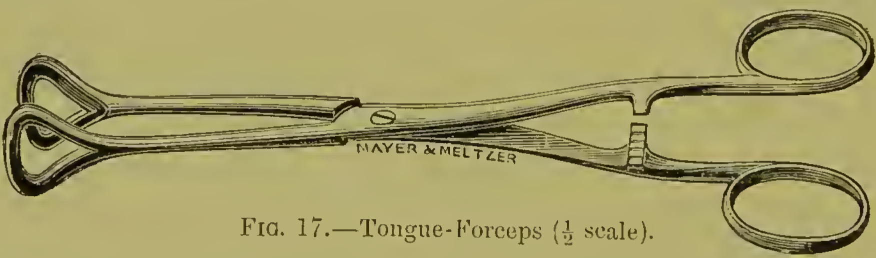


FIG. 17.—Tongue-Forceps ($\frac{1}{2}$ scale).

for inserting before commencing the administration or for introducing subsequently, should it be found advisable to keep the teeth apart.

The **tongue-forceps** shown in Fig. 17 is as efficient as any. Some administrators, following the recommendation of Lord

Lister, use an artery forceps for seizing the tongue. An ordinary tongue-forceps, however, has the advantage of serving vicariously as a sponge-holder.

A **small basin** should be at hand in case of vomiting, the non-occurrence of which cannot be prophesied with certainty in any instance.

In ordinary surgical practice a soft **towel** is essential for wiping out the corners of the mouth, for rubbing the lips and cheeks (p. 420), or for placing beneath the cheek of the patient as it lies upon the pillow.

A new, coarse, moistened **sponge**, about the size of a hen's egg, together with a bowl of water, ought always to be at hand when anæsthetising patients with intestinal obstruction or other affections attended by vomiting. A sponge is also useful when much mucus is secreted. Although the surgeon generally provides sponges for use during throat operations, the anæsthetist will do well to have at hand, in addition, a sponge such as that just described.

Instruments for the performance of tracheotomy should always be available.[1] Fig. 18 shows a convenient **emergency case,** which contains not only the appliances which have already been referred to (Mason's gag, tongue-forceps, wooden mouth-opener, and mouth-prop), but instruments for the performance of tracheotomy, viz. two tubes, a scalpel, a sharp hook, and a dressing-forceps which answers as a dilator.[2]

In **dental practice** the anæsthetist should have with him **several mouth-props** for keeping the teeth apart during the administration. Having tried numerous kinds, the author devised the props shown in Fig. 19. It is made of aluminium, and is so shaped that it adjusts itself to the angle made by the lower jaw receding from the upper. It is furnished with detachable rubber pads, which can be renewed from time to

[1] A case occurred in the author's own practice some years ago which showed the necessity of being prepared with tracheotomy instruments on *all occasions.* Had he not had a tracheotomy tube with him, it is highly probable that he would not have been able to rescue the patient from imminent death. The case is fully described on p. 538.

[2] This little case is manufactured by Messrs. Krohne and Sesemann, and is specially adapted for use in operating theatres and elsewhere when anæsthetics are being employed.

time. When in position it engages several teeth, so that there is no chance of a faulty loose tooth being injured. Five sizes

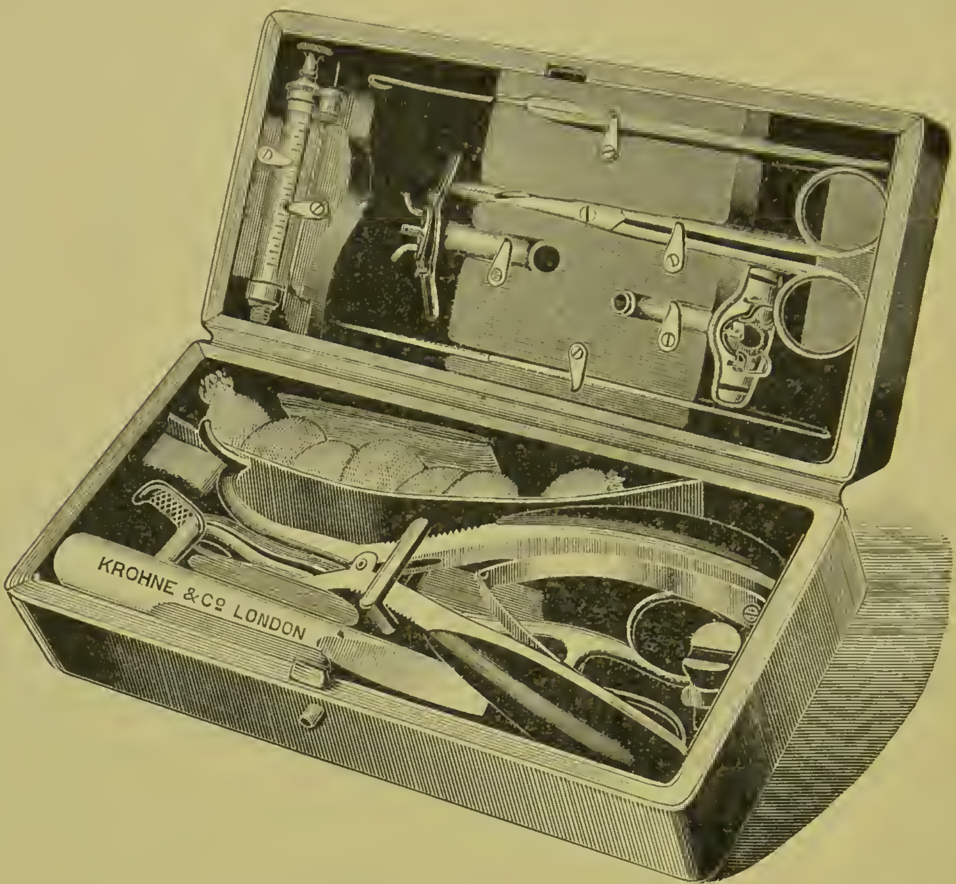


FIG. 18.—Emergency Case, containing Mason's Gag, Tongue-Forceps, Wooden Wedge, Mouth-Prop, Instruments for performing Tracheotomy, Hypodermic Syringe, and partition for remedies, such as Strychnine, etc.

are necessary. All props containing springs or screws are liable to break, to get out of order, or to be contaminated with

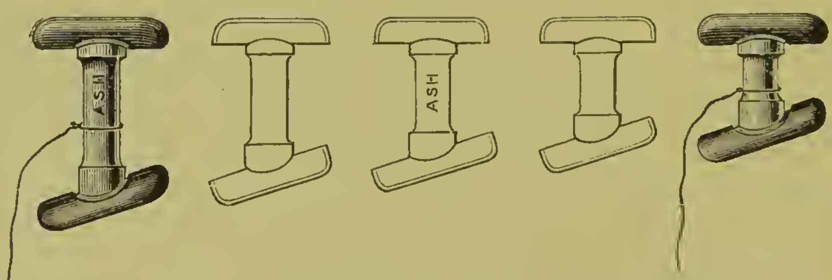


FIG. 19.—Set of five of the author's Mouth-Props for use in dental practice (half size).

blood, pus, etc. The props shown can be easily sterilised by boiling. All wooden or vulcanite props, although apparently

less cumbrous than those recommended, will be found to more frequently slip than the props shown in the figure.

A hypodermic solution of **morphine** may be required for use either before or during anæsthesia (Chap. XVI.).

Various **medicinal remedies** have been advocated for the treatment of alarming symptoms during or after anæsthesia, and opinions are still divided as to their relative efficacy. The author regards all such drugs as useless in combating conditions directly attributable to the action of the anæsthetic. As will be subsequently pointed out (Part IV.), the establishment of a free air-way, artificial respiration, and partial inversion are of far greater value than any other restorative measures with which we are acquainted. At the same time we must not lose sight of the fact that anæsthesia is frequently complicated by surgical shock of a circulatory type, so that an

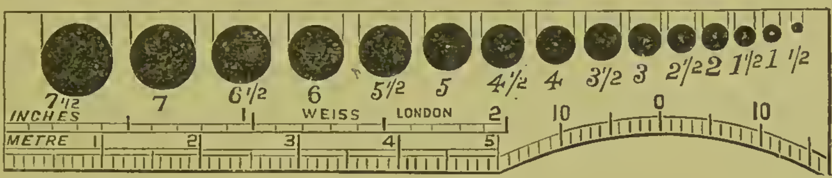


Fig. 20.—Pupillometer. (By kind permission of Mr. Edgar A. Browne.)

apparatus for the intravenous injection of saline fluid, and drugs such as **strychnine, adrenalin, ergotin,** and **digitalin** which, according to many authorities are useful in the treatment of surgical shock, should be in readiness when this condition is likely to arise. **Alcohol, ammonia, ether** for subcutaneous injection, and **atropine** have one and all their advocates; but it is questionable whether they are of any real value in the treatment of conditions brought about by anæsthetics. The last-named drug is strongly recommended by some physiologists as a preventive against chloroform syncope (p. 503). A cylinder of compressed **oxygen** may with advantage be kept in readiness in public institutions in which anæsthetics are given on a large scale.

A **pupillometer** (Fig. 20) is often of use in studying and recording the phenomena of anæsthesia.

I. ASEPTIC PRECAUTIONS: CLEANSING AND DISINFECTING APPARATUS AND APPLIANCES

Although it might be going too far to say that there is as great a need for the observance of aseptic and antiseptic principles in the administration of anæsthetics as in surgery proper, it is highly important that such principles should, as far as possible, be adhered to. Whilst in ordinary surgical cases it is unnecessary for the anæsthetist to do more than thoroughly cleanse his hands and to see that the inhalers and appliances he employs are scrupulously clean before use and carefully washed afterwards, there are certain cases in which special care and precautions must be adopted. These will be presently referred to.

All inhalers and other apparatus should be capable of being thoroughly washed, and any whose mechanism might be injuriously affected by hot water should be discarded as unsuitable. It would be impossible, even were it advisable, to sterilise after each administration the face-pieces, bags, etc., employed. But in general surgical practice it should be a matter of routine, immediately the administration is at an end, to twice wash in hot water everything that has been used; and should any of the apparatus employed have been contaminated by pus, blood, vomited matters, etc., hot weak carbolic lotion (about 1 : 60) may be advantageously substituted for the plain water. It is a mistake to suppose that Clover's inhaler is likely to be damaged by this simple cleansing process.

Special precautions are necessary when anæsthetising patients for operations upon the head, face, mouth, nose, throat, neck, and shoulders. In such operations the surgeon and the anæsthetist are brought into close relations with one another, and it is the duty of the latter, by preparing his hands, and carefully disinfecting, and if possible sterilising, his appliances, to adapt himself to the requirements of the former. Thus, prior to an operation within the mouth, nose, or throat, gags, props, and mouth-tubes should be boiled, and perfectly new sponges, which have previously been placed in 1 : 20

carbolic lotion and have subsequently been washed out in water, should be in readiness. In operations about the face and neck, the Skinner's mask should either be sterilised before use, or its edges protected by sterilised lint or gauze wound round the circumference of the mask, and pinned.

In dental practice the Mason's gag and all mouth-props should be thoroughly washed after use and sterilised by boiling before being again employed. It is quite conceivable that, in the absence of these precautions, conditions such as pyorrhœa alveolaris might be transmitted from patient to patient.

J. THE ADMINISTRATION FROM THE PATIENT'S POINT OF VIEW

Patients about to be anæsthetised are usually in a state of nervous tension or apprehension, and should be treated with the utmost kindness and consideration. They should not be hurried; the necessary preparations for the operation should not be made in their presence; and everything should be done to lessen the anxiety and discomfort which must necessarily be associated with the contemplated surgical procedure. Reference has already been made to the importance of punctuality on the part of those engaged in the operation, and to certain points in connection with the posture of the patient during the induction of anæsthesia. The room should be kept quite quiet and all talking avoided during anæsthetisation. It must be remembered that sounds may seem to the half-anæsthetised patient to be much louder than they really are, and that the power of hearing disappears at a late point in the induction stage. The author has on several occasions known patients to complain of the talking of bystanders whilst being anæsthetised.

PART III

THE ADMINISTRATION

CHAPTER IX

THE ADMINISTRATION OF NITROUS OXIDE

THE reader is referred to Chapter I. p. 7 for a short account of the discovery and early use of this anæsthetic; to Chapter II. p. 19 for information upon its chemical and physical properties; to Chapter IV. p. 95 for a *résumé* of the principal experimental work that has been done concerning its physiological action; and to Chapter V. p. 145 for remarks as to its safety and suitability in general surgical practice.

In the early days of its administration nitrous oxide was rarely inhaled in a state of purity. Not only was there difficulty in obtaining the gas in this state, but when obtained it was inhaled in such a way that considerable quantities of air also gained admission to the lungs. It thus happened that the effects produced were usually those of intoxication rather than of anæsthesia, although, as on the memorable occasion when Horace Wells himself inhaled "laughing gas," complete unconsciousness was sometimes induced. By the time that this anæsthetic had found its way to England, Colton's[1] experience had become so great that he was able to formulate rules for its successful administration in dental practice. He urged the necessity of excluding all atmospheric air, and of administering the gas by means of an apparatus with inspiratory and expiratory valves. But whilst air-exclusion was thus rigidly practised when employing nitrous oxide for such short operations as those of dentistry, cases were from time to time

[1] *Brit. Journ. Dental Science*, 1868, p. 257.

recorded in which, by the alternate inhalation of nitrous oxide and air, it was found possible to maintain more or less complete anæsthesia for protracted surgical operations.[1] Clover pointed out the advantage, in such cases, of allowing air to be breathed concurrently with the nitrous oxide; and we are indebted to him for many improvements in inhaling apparatus.[2] By the use of a nose-piece, Clover and Coleman introduced the system of maintaining anæsthesia during prolonged dental operations—a system which has, in more recent times, been successfully revived and extended (p. 297). In 1868 Dr. E Andrews[3] of Chicago published several cases in which, by mixing oxygen with nitrous oxide, he had obtained a more satisfactory form of anæsthesia than with nitrous oxide alone; but, curiously enough, his interesting observations failed to attract the attention they deserved; and it was not till ten years later that Paul Bert again drew attention, by a series of interesting experiments to be subsequently described, to this system of anæsthetisation. Bert's researches led him to believe that in order to obtain nitrous oxide anæsthesia in the presence of oxygen or air, it was necessary that the patient should be subjected to an increased atmospheric pressure; but experience has proved that this increased pressure is not absolutely necessary. It is now established beyond all doubt that by employing certain percentages of atmospheric air with nitrous oxide a better form of anæsthesia can be obtained than with the undiluted gas; and that by using oxygen instead of atmospheric air, a still better form of anæsthesia is obtainable. There is, in fact, no doubt whatever that the complete exclusion of oxygen, which was at one time considered imperatively necessary, is opposed to those general principles which should guide us in administering anæsthetics.

It will be convenient to consider nitrous oxide under the following sections:—

Section I. The administration of pure nitrous oxide;

Section II. The administration of definite mixtures of nitrous oxide and air;

[1] See *Brit. Journ. Dental Science*, 1868, pp. 393 and 485; and 1869, p. 46. Also *Brit. Med. Journ.*, 2nd May 1868. Also Turnbull's *Artificial Anæsthesia*.

[2] *Brit. Journ. Dental Science*, Sept. 1868, p. 485.

[3] *Ibid.*, 1869, p. 22.

Section III. The administration of nitrous oxide with indefinite quantities of air;

Section IV. The administration, at ordinary atmospheric pressures, of definite mixtures of nitrous oxide and oxygen;

Section V. The administration, under increased atmospheric pressures, of definite mixtures of nitrous oxide and oxygen (Paul Bert's system); and

Section VI. The administration, at ordinary atmospheric pressures, of nitrous oxide with varying proportions of oxygen.

Section I.—The Administration of Pure Nitrous Oxide

A. APPARATUS AND METHODS OF ADMINISTRATION

Nitrous oxide is supplied by the manufacturers in iron and steel **cylinders** which contain the agent in a liquid state under considerable pressure.[1] Those yielding 50 gallons of gas are most commonly used; but 25-gallon cylinders are preferable when, as is often the case, portability is a matter of consideration. 100-gallon cylinders are more adapted for hospital practice. Every cylinder is furnished with a lable stating its weight when empty and when fully charged; so that, when weighed, the quantity of nitrous oxide present may always be ascertained. 7½ ounces of liquid nitrous oxide will furnish about 25 gallons of gas. Full, or nearly full, cylinders may at once be known by the liquid sound which they emit when sharply tapped with the foot-key or some similar article. It is always advisable to have two cylinders coupled together, in case one should work badly or fall short during the administration. It is also a good plan to make it a rule on all occasions to work first from the cylinder of one side, and only to go on with the second or reserve cylinder in the event of the other becoming exhausted. If the administrator work indiscriminately from both cylinders he may easily allow the supply of the anæsthetic to fall too low. Care should be taken to thoroughly turn off the gas after each administration, otherwise leakage will gradually occur and the cylinder become empty. Each cylinder is furnished with a screw-valve or tap, by turning which with a foot or hand-key, gaseous nitrous oxide escapes.

Fig. 21 shows two cylinders coupled together. The author has had a lengthened experience with these side-valve cylinders, and believes them to be better than any others. They have the great advantage that they require but a very simple form of stand to render them perfectly stable

[1] The author has been informed by one of the manufacturers of this gas that the pressure within the cylinders which they supply often registers nearly 1000 lbs. to the square inch.

whilst being worked; and when fitted with the easily acting valves invented by Messrs. Barth and Co. they answer every requirement. It is only quite recently that these side-valve cylinders have been brought into a state of perfection. When they were first used they were not satisfactory; and to the late Dr. C. E. Sheppard belongs the credit of removing the objections which were formerly attached to their use.[1]

Some years ago[2] the author made a special study of the various methods then in use for administering nitrous oxide. He came to the

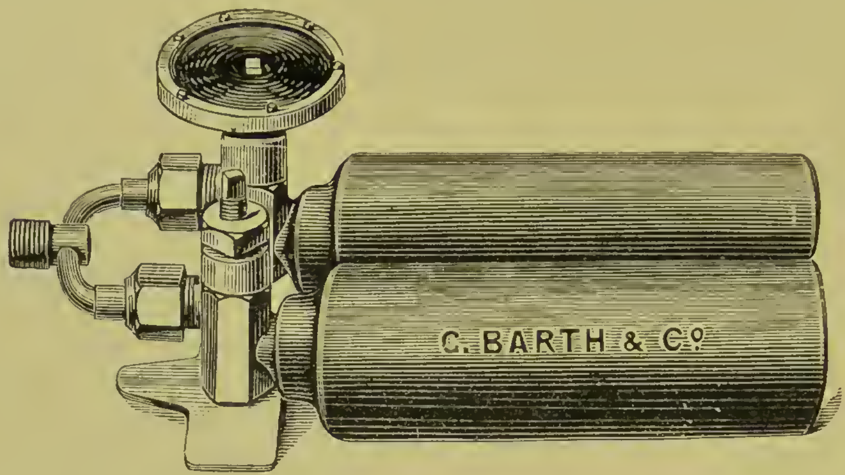


FIG. 21.—Two Side-valve Cylinders, with Stand, Double Union, and Foot-key.

conclusions—(1) That accurately fitting valves were essential at the commencement of the inhalation, in order to make sure of the rapid exit of air from the lungs; (2) that, so far as the available resulting anæsthesia was concerned, there was a decided advantage in allowing a certain amount of re-breathing of nitrous oxide towards the *end* of the inhalation; (3) that although there were certain hygienic objections to this re-breathing, it was nevertheless very convenient to be able to resort to it as a measure for securing a longer anæsthesia, or for successfully terminating an administration when the supply of nitrous oxide had unexpectedly fallen short. There was no apparatus which would allow of two valves being in action for the earlier or middle stages of the administration and

[1] See an interesting paper by Dr. C. E. Sheppard, *Lancet*, 21st Feb. 1891, p. 424—"Difficulties connected with the Use of Nitrous Oxide Bottles in the Horizontal Position." Dr. Sheppard found that the 50-gallon cylinders supplied by Messrs. Barth and Co. had a capacity of 50·5 cubic inches, and taking the sp. gr. of the liquid to be ·908 at 45° F. and the weight of the 50 gallons of nitrous oxide gas thus liquefied to be 15 ounces, the space occupied in the bottle by the liquid was 28·6 cubic inches, roughly three-fifths of the total capacity. He argued that as the cold produced by the nitrous oxide passing from the liquid to the gaseous form is very intense, superficial solidification of the nitrous oxide may take place, and the snow-like body thus formed may temporarily choke the tube. By bringing the inner orifice of the exit tube above the level of the liquid in the cylinder, all choking with liquid or solid nitrous oxide is obviated.

[2] See "An Inquiry into Several Methods of administering Nitrous Oxide" (*Journ. Brit. Dent. Assoc.*, vol. vii., 1886, p. 86).

would subsequently permit re-breathing. The author therefore devised [1] and used a face-piece with thin rubber valves which could, at the will of the administrator, be thrown out of action, and allow of the gas-bag being used very much as Clover's "supplemental bag" was used,[2] *i.e.* for to-and-fro breathing. Subsequently he placed these rubber valves in a little box between the stopcock and the face-piece,[3] so that plain

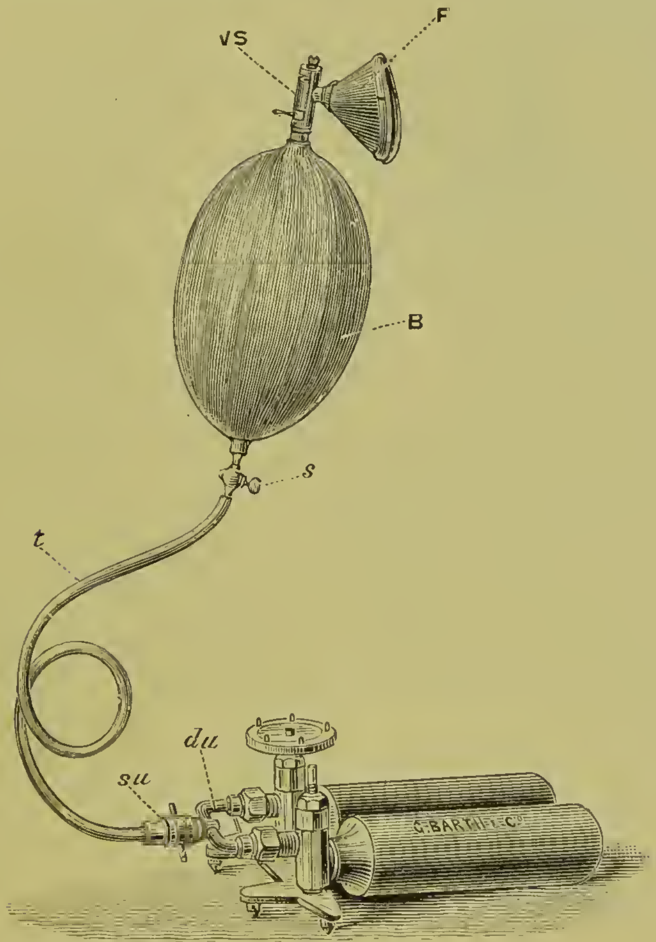


FIG. 22.—Complete Apparatus for the Administration of Nitrous Oxide Gas.

valveless face-pieces could be attached. The valves were thrown into and out of action at will by turning a small handle surmounting the valve-box. A short trial of this apparatus led to his placing the valves and the two-way stopcock *in one chamber*, in other words, to the apparatus which he now employs (Figs. 22, 23, and 24).

The apparatus which the author has found to give the best results in the administration of nitrous oxide is shown in the accompanying figure (Fig. 22). It is made by Messrs. Barth and Company. From the single

[1] *Lancet*, 9th May 1885.
[2] *Brit. Med. Journ.*, 14th February 1874.
[3] See *Brit. Med. Journ.*, 27th August 1887, p. 452.

union (*su*) the tube (*t*) passes to join the bag (B).[1] A little stopcock (*s*) is useful in case it should be wished to disconnect a full bag from the rest of the apparatus. The bag (B) has a capacity of about two gallons. There is certainly an advantage in having the bag as near as possible to the face-piece; for not only may its movements be readily watched, but the patient can take the most forcible inspirations without any of that impediment which is likely to be experienced when a tube exists between the bag and face-piece. The valved stopcock (VS), which is the most important part of the apparatus, connects the gas-bag (B) to the face-piece (F). This stopcock, shown more in detail in Figs. 23 and 24, contains two thin valves of sheet india-rubber, which may be thrown into or out of action by turning the tap (T) (Fig. 23).

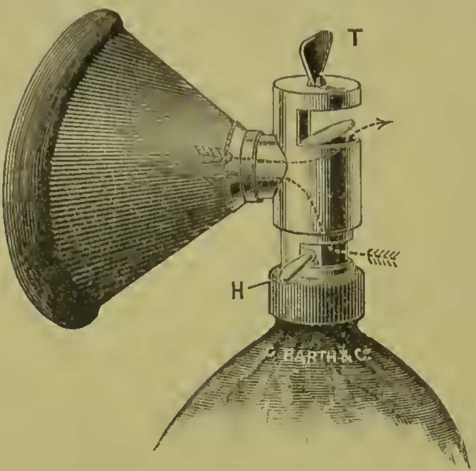


Fig. 23.—The author's Valved Stopcock, with Face-piece, etc., for administering Nitrous Oxide.

The handle (H) determines whether air or gas is admitted to the face-piece. When T and H are arranged as in Fig. 23, air enters the stopcock and is breathed out through valves in the direction shown by the arrows. Fig. 24 shows in diagrammatic section the mechanism of the valved stopcock. It has two slots cut out of its circumference, an upper slot (US) and a lower slot (LS). There are two inner cylinders which revolve immediately inside the outer casing of the stopcock. The upper inner cylinder (UIC) is worked by T, the lower (LIC) by H. The upper cylinder carries the inspiratory and expiratory valves (IV and EV). The lower has a slot in its walls (shown in dotted lines) which can be made to correspond with LS by turning H. When T is turned as in the diagram, the upper slot is open, both valves act, and expirations escape as shown by the arrow. When T is turned completely round, the upper inner

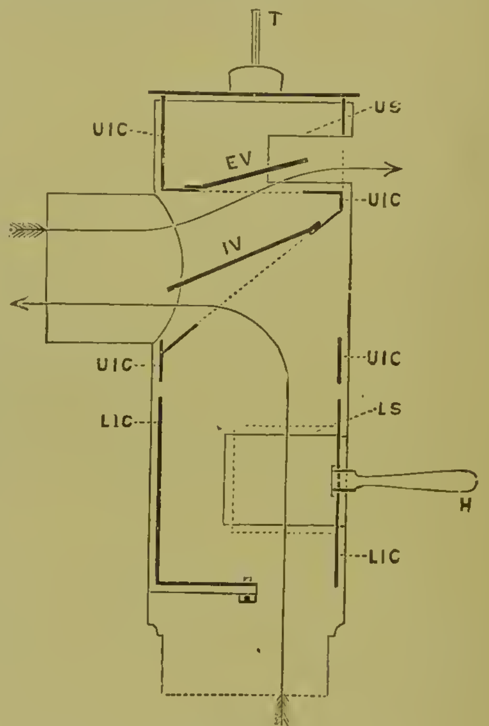


Fig. 24.—Diagrammatic Section of Valved Stopcock.

[1] Some administrators interpose what is known as a "quieter" between the gas cylinders and this tube, but when properly managed the noise of issuing gas is so slight as to render such a complication unnecessary.

cylinder rotates, the valves are thrown out of action, the upper slot is closed (as shown by dotted line), and to-and-fro breathing results. Whether air or nitrous oxide be admitted to the face-piece will depend upon the position of H. When H is placed as in the diagram, the inner cylinder which it controls allows of a free passage of gas from the bag to the face-piece (as shown by the long arrow). Should H be moved round, the inner cylinder would cut off the way to the bag and would open the air slot (LS), so that air and not gas would be respired (Fig. 23). The valved stopcock therefore permits—

(1) *Air* to be breathed { (*a*) *through valves*, or (*b*) *backwards and forwards.*

(2) *Nitrous oxide* to be breathed { (*a*) *through valves*, or (*b*) *backwards and forwards.*

In actual practice we arrange the stopcock so that the patient may first of all breathe air through valves, and then nitrous oxide through valves; and we only call into play the to-and-fro breathing of nitrous oxide under special circumstances, to which future reference will be made. The arrows in Fig. 23 indicate the direction taken by the air current when the face-piece is applied to the face, *i.e.* before nitrous oxide is turned on by the handle (H). The valves should work easily. They should be examined before use to see that they do not stick and that they have in no way become caught in the orifices which they guard. The whole stopcock has wide channels through it, in order that respiration may take place freely. This is especially necessary with regard to the air-hole, so that when the apparatus is applied to the face the patient may feel no impediment in filling his chest with air. Most of the older forms of apparatus have channels far too small for successfully administering nitrous oxide gas. The face-piece should be furnished with a broad soft air-cushion, which should be partly distended with air by means of the little tap for the purpose. Two or three sizes are necessary. The angle of the face-piece cushion, into which the bridge of the nose fits, should be acute, in order that the face-piece may accurately fit the patient. No apparatus can be considered satisfactory unless it allows the patient to *breathe air through valves* before nitrous oxide is turned on. The reason for this statement will be presently discussed.

In **administering nitrous oxide** the following directions must be observed:—

1. *Make sure that there is a sufficient supply of gas before commencing.* Patients vary as to the quantity of nitrous oxide required to produce anæsthesia. The average may be roughly placed at six gallons per patient. Tall, plethoric, or alcoholic subjects may require considerably more than this. When there is much hair around the mouth it is often difficult to wholly exclude atmospheric air, and hence more nitrous oxide

than usual may be needed. In such cases it is a good plan to first adjust the face-piece and then cover its cushion with a napkin which has been wrung out in water and folded two or three times longitudinally. Anæmic and feeble subjects, as well as children, may usually be anæsthetised by two or three gallons of the anæsthetic.

2. *Run a small quantity of nitrous oxide through the apparatus to free it from air; fill the bag to about two-thirds; and then turn off the screw-valve of the cylinder.* The apparatus is now charged and ready for use.

3. *Make sure that the valves are in good order.*

4. *Adjust the mouth-prop, should one be necessary* (see p. 258), and request the patient to commence breathing through the mouth. It is curious that even educated people will often breathe through the nose under the impression that they are breathing through the mouth. As oral breathing is essential for success in administering nitrous oxide, it is well to make certain, before applying the face-piece, that the patient understands what is required of him.

5. *Gently adjust the face-piece.* Success in giving nitrous oxide largely depends upon the accuracy with which the face-piece fits. If the face-piece fit accurately and the patient breathe through the mouth, a particular sound will be produced by the acting valves by which the anæsthetist will know that everything is satisfactory. Some patients hold their breath and pretend to be breathing deeply when in reality they are not doing so. Unless the patient can be made to freely fill his chest with air he certainly will not inhale nitrous oxide satisfactorily when the latter is substituted.

6. *When the patient is observed to be freely filling his chest with air through the apparatus, nitrous oxide may be admitted.* At the moment that this is done the gas-bag must not be over-distended: it should be about two-thirds full.

7. *The bag should be kept nearly full throughout the administration.* At the same moment that nitrous oxide is admitted, the administrator should gently allow a stream of gas to enter the bag from the bottle. Fig. 25 shows the administration of nitrous oxide for a dental operation by means of the apparatus which the author finds to answer best. An attempt should

be made to give the gas as nearly as possible slightly above atmospheric pressure. Any evidence of excitement must be met by a slight increase in the fulness of the bag, as such

FIG. 25.—The Administration of Nitrous Oxide for a Dental Operation (from a photograph).

symptoms are probably due to the ingress of air by the side of the face-piece.

8. *To-and-fro breathing of nitrous oxide should not be permitted except under certain circumstances, and then only towards the end of the administration.*

A great deal of discussion has taken place as to the propriety of allowing the patient to re-breathe nitrous oxide. The matter admits of consideration from two points of view, which may be called (*a*) the hygienic, and (*b*) the practical. From the hygienic point of view, it is clear that the re-breathing of nitrous oxide should not be practised unless the bag and stopcock are thoroughly washed (p. 260) after every administration. From the practical point of view, however, the question assumes a different aspect. The author is not referring to to-and-fro breathing *early* in the administration; this is inadmissible by reason of the dilution of nitrous

oxide which would result from its admixture with the considerable proportion of atmospheric air previously contained in the air-passages of the patient. He refers to to-and-fro breathing towards the *end* of the administration, *i.e.* when most of the air has been washed out of the air-passages by the free inhalation and exhalation of nitrous oxide through valves. For the sake of clearness let us suppose that we have six gallons of nitrous oxide ready for an administration. We allow the patient to breathe four gallons of this through valves, so that his lungs rapidly lose nearly all the air which they contained, and all expirations escape into the surrounding atmosphere. The valve-action is now stopped, and the patient is made to breathe the remaining two gallons of nitrous oxide backwards and forwards into the bag. Anæsthesia will take a little longer to become established than usual, because of a small percentage of oxygen (from the residual air of the lungs) being still in the to-and-fro current. Had no to-and-fro breathing been permitted, the phenomena of nitrous oxide anæsthesia would have come on earlier, because of the quicker expulsion of all oxygen. The longer inhalation leads to a longer available anæsthesia, so that from some points of view this plan of administering nitrous oxide has distinct advantages. That the re-breathing *towards the end of the administration* has no bad effect upon the patient the author has proved by a very large number of administrations. He has found, it is true, that the recovery is not quite so rapid as when nitrous oxide is continuously inhaled in the usual manner ; but this slight difference is connected with the longer periods of inhalation and anæsthesia. The longer we allow a patient to inhale an anæsthetic, the longer, as a rule, will he be in regaining complete control and consciousness. Some have objected that this method of re-breathing towards the end is more "asphyxiating" than the ordinary method. But the reverse is more correct if by "asphyxiating" is meant the occurrence of symptoms dependent upon the deprivation of oxygen. Were it not, therefore, for the hygienic objections above alluded to, the plan of administering nitrous oxide just described would certainly have advantages over others. The author has analysed the contents of the gas-bag, at the end of an administration, after to-and-fro respiration, and has found from 1·2 to 2·4 per cent of oxygen in a two-gallon gas-bag which, from the moment when to-and-fro breathing commenced to the termination of the administration, remained full or nearly full.[1] He once administered nitrous oxide to a patient on six different occasions. On three of these he adopted the ordinary method, allowing the valves to act throughout, and all expirations to escape. On the three other occasions the patient was anæsthetised by allowing her expirations for the first and major part of the inhalation to escape, and then, when the lungs had been well washed out with the gas, to-and-fro breathing was permitted. The times (*a*) of inhalation and (*b*) of resulting anæsthesia were taken on each occasion, and are of much interest as showing the slight but distinct gain in available anæsthesia when to-and-fro breathing is permitted towards the close

[1] Full details of the experiments are given in the *Journ. Brit. Dent. Assoc.*, vol. vii., 1886, p. 86.

of the administration.[1] The average available anæsthesia in the absence of to-and-fro breathing was 39 seconds; whilst when to-and-fro breathing was permitted, as described, a workable anæsthesia of 56 seconds was obtained.

B. THE EFFECTS PRODUCED BY PURE NITROUS OXIDE

Owing to the rapidity with which the phenomena of nitrous oxide anæsthesia make their appearance, it is somewhat difficult to classify them. But as this anæsthetic, more particularly when administered with oxygen, closely resembles ether and chloroform, it has been thought best to adopt the same plan that will be followed when describing the phenomena which attend the administration of the last-named agents.

First Degree or Stage.—Nitrous oxide has a peculiar sweetish taste which is by no means unpleasant. Great variation will be found to occur in the sensations which patients experience during the inhalation of this agent. When administered in the proper manner, and with due attention to details, these sensations will be more likely to be of an agreeable than of a disagreeable character. Should the apparatus possess valves which do not work easily, or should the channels through which the gas is made to pass be too small, or should the patient from want of confidence or knowledge breathe in a shallow and restricted manner, or through the nose, an unpleasant experience may result. A feeling of warmth in the lips and an indescribable though pleasant numbness over most of the body are amongst the first sensations noticed. The patient has an irresistible desire to breathe more deeply and quickly. These sensations are rapidly followed by a peculiar and pleasurable "thrilling" which hardly admits of description. Some tinnitus may be present, and curious sensations, such as fulness and expansion of the head, are occasionally experienced. As a general rule, however, loss of consciousness comes on before the patient has time, so to speak, to define his feelings. The respiration will be observed to be deepened and quickened in response to the desire of the patient just alluded to. The pulse, as Sir George Johnson pointed out, grows fuller under the finger; and,

[1] *Journ. Brit. Dent. Assoc.*, vol. vii., 1886, p. 342.

according to Dr. George Oliver,[1] its calibre is somewhat increased at this stage. The increased fulness is probably due to constriction of the systemic arterioles. The power of hearing persists throughout this stage. The time which elapses between the commencement of the inhalation and loss of consciousness is extremely short, being probably about 20-30 seconds on the average.

Second Degree or Stage.—With the loss of normal consciousness, disturbed psychical states are liable to arise. As a general rule the patient gives little or no evidence of such disturbance, more especially if allowed to remain perfectly quiet. If roughly handled he is liable to become excited and to move his arms or legs. When nitrous oxide is properly administered, symptoms of excitement are, with the rarest possible exceptions, conspicuously absent. Any injury inflicted during this stage may produce immediate reflex effects, such as shouting, co-ordinate or inco-ordinate movement, but it would not be accurately remembered by the patient. Nitrous oxide is often accused of producing imperfect anæsthesia, because operations are sometimes commenced at this stage. Dreams are common, but are rarely distinctly remembered. Sometimes they are so pleasant that, at the conclusion of the administration, the patient, who is unaware of having been deeply anæsthetised, is sorry to be disturbed. On other occasions dreams are of the most disagreeable character. It is a curious fact that unpleasant dreams are more common under nitrous oxide *per se* than under nitrous oxide administered with oxygen—probably because the anæsthesia in the latter case is deeper, so that operations or other interferences, which in the case of nitrous oxide itself might leave some disturbed impressions, are not capable of doing so when the anæsthesia is more profound. Erotic dreams are occasionally experienced.[2] The respiration is still quicker and deeper than normal, and, save perhaps for an occasional act of swallowing, is perfectly regular. In some cases a spurious form of stertor may occur and is to be disregarded. The pulse is still full and a trifle quicker than in the previous stage. The conjunctiva is quite sensitive to touch. The pupils usually grow larger as the

[1] *Pulse-gauging*, 1895, p. 82. [2] See *Lancet*, vol. ii., 1872, p. 721.

administration proceeds. The features gradually lose their normal colour. Duskiness or lividity is most common in patients of a florid type, anæmic and sallow persons showing very little alteration in appearance. The eyelids are usually affected by slight twitching; and as the inhalation proceeds they exhibit a tendency to separate and to display the subjacent globes.

Third Degree or Stage.—The first indication that the patient is passing or has passed into the third stage of anæsthesia is usually afforded by the **respiration.** The breathing, which has hitherto preserved its rhythm, now loses it, and a peculiar and characteristic throat sound, sometimes described as "stertor," becomes audible. This sound is most probably due to irregular and spasmodic elevations of the larynx towards the epiglottis and base of the tongue, and indicates a tendency to obstruction in the air-way at this point. Deep snoring or snorting breathing may be met with in certain cases, and may either necessitate the withdrawal of the anæsthetic before the time has come, so to speak, for the deeper throat sound, or may altogether mask the latter. As has been pointed out, the position of the head and the conformation of the upper air-passages have an important influence in bringing about or retarding stertor. At or about the moment at which the characteristic guttural sound occurs, the rhythm of breathing is liable to be further interfered with by clonic spasm of thoracic and abdominal muscles. Sometimes, indeed, a sudden irregularity in breathing, totally independent of laryngeal closure or "stertor," and entirely the outcome of this muscular spasm, is the first indication of deep anæsthesia. It occasionally though rarely happens that, instead of respiration undergoing the changes mentioned, it becomes somewhat feeble; or expiration becomes prolonged and rather strained. These phenomena should, in the presence of other signs of anæsthesia, be taken to mean that the administration has been pushed sufficiently far. The author found by timing 60 consecutive nitrous oxide administrations that the average number of respirations required to produce deep anæsthesia was 29·2. The lowest recorded number was 6; the highest 72. It need hardly be pointed out that it is very exceptional for deep anæsthesia

to occur after only six inspirations. The author has, however, met with a remarkable case in which the muscular phenomena characteristic of full nitrous oxide anæsthesia appeared during the third inspiration. The patient was the subject of (?) pernicious anæmia (p. 163).

The **circulation** is well maintained during nitrous oxide anæsthesia, provided that care be taken to prevent too great a degree of asphyxia. From the observation of a considerable number of cases the author has found that, in most instances, the heart's action becomes more and more accelerated as the administration proceeds, and that, when the usual phenomena of full anæsthesia occur, the pulse is often very rapid, especially in patients with naturally quick cardiac action. A pulse of 120 immediately before the administration may, for example, rise to 160 or more when clonic movements, etc., occur; whereas a pulse of 80-90 at the beginning of the inhalation will often not exceed 100 or 110 in the third stage. As the pulse increases in frequency it loses its previous fulness; and this change is of course most conspicuous in patients with quick cardiac action. According to the late Sir George Johnson,[1] the small pulse observed at the acme of the inhalation is due to less blood reaching the left side of the heart. Immediately air is admitted by the withdrawal of the anæsthetic, the pulse abruptly undergoes a marked change. It at once becomes slower and fuller. A pulse of 140 at the acme of anæsthesia may thus suddenly drop to about 80 per minute before the effects of the anæsthetic have passed off. As consciousness becomes restored, the pulse-rate again rises, as the result of mental conditions, after-pain, etc.

Various **muscular phenomena** may appear. The extremities are sometimes, though by no means invariably, flaccid. When respiration undergoes the changes above referred to, the arm, if raised by the administrator, will generally fall. But there is a tendency for clonic muscular contractions to occur in all cases, and for tonic spasm to arise in many. In the course of a recent investigation the author showed[2] that the so-called "jactitation" of nitrous oxide, which in one case may be little

[1] *Brit. Med. Journ.*, 21st and 28th April 1894.

[2] See "On the Effects produced in the Human Subject by the Administration of Definite Mixtures of Nitrous Oxide and Air, and of Nitrous Oxide and Oxygen" (*Trans. Royal Med. Chir. Soc.*, vol. lxxxii., p. 163).

more than a subsultus, whilst in another it may be a widely diffused epileptiform seizure, is an intercurrent condition due to want of oxygen, and not an essential feature of true nitrous oxide anæsthesia. In some cases the facial muscles are chiefly affected by the convulsive seizure; in others the whole body mildly oscillates, the spasm apparently chiefly affecting the trunk muscles; in others, the hands, legs, and arms alone may twitch; whilst in a fourth group of cases the neck may be affected by barely perceptible clonic spasm, so that the head is felt to move with fine rhythmic jerks in one or other direction.

There is little doubt that the intermittent elevation of the larynx, the irregular contractions of the thoracic and abdominal muscles, and the clonic movements of the extremities are correlated. Tonic muscular contraction is sometimes very pronounced, not only in the extremities, but in the neck, back, and other parts; some patients, indeed, pass into an opisthotonic condition during this stage. Micturition very rarely occurs, but is sometimes met with in children when the clonic movements are at their height. Defæcation is extremely uncommon. Horsley has shown[1] that in deep nitrous oxide anæsthesia the superficial plantar reflex is abolished, but the deep patellar reflex is maintained. Eulenburg's experiments[2] also show that in the asphyxial state, whether induced mechanically or by drugs such as nitrous oxide, the superficial reflexes disappear before the deep. Dr. Buxton[3] found that one-third of the men, and nearly one-third of the women, anæsthetised by him at the Dental Hospital displayed ankle-clonus under nitrous oxide.

The **pupils** in the majority of cases are dilated in deep nitrous oxide anæsthesia. In some cases, even though the anæsthetic has been freely administered, they remain of moderate size or even contracted.

The **conjunctival reflex**, which will have persisted during most of the administration, now either becomes less marked, or disappears. It cannot be depended upon as a guide, for it may sometimes be elicited even when wide dilatation of the pupils,

[1] *Brain*, vol. vi. p. 369.
[2] *Centralblatt für med. Wissensch.* No. 6, 1881.
[3] *Brit. Med. Journ.*, 24th September 1887.

and other signs indicative of the anæsthetic having been pushed as far as is advisable, are present. The corneal reflex usually persists.

The **colour of the features** is invariably altered, the change being most noticeable at the height of the muscular phenomena. Flabby and apoplectic-looking patients usually become deeply cyanosed when fully anæsthetised by nitrous oxide.

With perfectly pure nitrous oxide, with absolute coaptation of the face-piece, and with perfectly acting valves, the **time taken to produce full anæsthesia** is, on the average, about 56 seconds; but, as we have seen, the duration of inhalation will depend upon the type of subject.

C. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

The anæsthesia obtainable by nitrous oxide, particularly when that anæsthetic is administered free from oxygen, is distinctly lighter than the anæsthesia of ether or chloroform. In the vast majority of cases, however, complete insensibility of short duration may be depended upon. The author has met with two or three instances in the course of his experience in which he has been unable to obtain that absolute and dreamless unconsciousness which is procurable with other anæsthetics.

It is often a matter of some difficulty to decide at what particular moment anæsthesia is at its height. As a general rule it is best to wait until stertor or slight clonic muscular twitching is produced. In dental practice the administration may be conducted till two or three stertorous breaths have taken place, but when the oral or nasal cavity is not to be involved in the operation the surgeon may commence his incision or other procedure when stertor first becomes audible. For reasons already given (p. 274), to-and-fro breathing towards the close of a nitrous oxide administration is advantageous in many cases, postponing as it does the onset of stertor and jactitation, and leading, therefore, to a more lengthened available anæsthesia period. In the absence of any re-breathing, asphyxial phenomena may arise before the conjunctival reflex

vanishes. When re-breathing is permitted, the administration may usually be continued till the conjunctiva loses its sensibility, and as there are less stertor and muscular movement with this method, the results will be better from the surgical point of view.

Although the extraction of a tooth during imperfect anæsthesia may not give the patient the sensation which we call pain, the operation may, under such circumstances, produce such a horrible and ill-defined feeling, or give rise to such an unpleasant dream, that it is questionable whether anything has been gained by the inhalation. In addition to these considerations, the performance of an operation during imperfect anæsthesia may be attended by much inconvenient tonic muscular spasm, which, in dental surgery, is objectionable from the liability of extracted teeth, etc., to fall backwards during opisthotonos.

In one or two cases the author has known prolonged and somewhat difficult expiration to replace other signs of anæsthesia. He has, moreover, met with cases in which, just at the acme of anæsthesia, the patient has made a sudden attempt at retching. Under such circumstances as these, the administration should be discontinued. Any marked feebleness of pulse or respiration should also be taken as an indication to remove the inhaler. Dilatation of the pupils is usually present in deep nitrous oxide anæsthesia, though it cannot be relied upon as a guide.

D. RECOVERY PERIOD: DURATION OF ANÆSTHESIA AFTER INHALATION

With the removal of the face-piece, or with the admission of air by other means, the recovery period commences. Sometimes, and especially in patients who have become markedly stertorous, the withdrawal of the anæsthetic does not necessarily involve the immediate admission of air to the lungs. In other words, a more or less occluded state of the upper air-passages may persist for a while and so retard the usual process of recovery. Other things being equal, the more rapidly and freely atmospheric air gains access to the lungs,

the more quickly will the patient recover. One of the first effects of the admission of air is observed in the pulse, which suddenly becomes much slower and fuller. Stertor, anoxæmic convulsion, and lividity now quickly vanish; and the dilated pupils begin to grow smaller. A secondary dilatation of the pupil may be observed during the recovery period.

The anæsthesia which persists after a single, continuous administration of pure nitrous oxide is known in dental practice as the **available anæsthesia**. The duration of this anæsthesia is, on the average, about **30 seconds**. There is considerable difficulty in deciding when true anæsthesia actually terminates, and this no doubt accounts for the discrepancies in the statements made by various authors. The period of available anæsthesia is to a certain extent dependent upon that of the inhalation; a long inhalation being followed, as a general rule, by a long anæsthesia, and *vice versa*. Moreover, in dental operations the duration of anæsthesia will not unfrequently be found to be influenced by the position of the patient's head, and more especially by the position of his tongue, during the extraction. Should the head be fully extended and the operation upon the upper jaw, nitrous oxide will have every chance of quickly escaping, and consciousness may thus be rapidly regained. If, however, the head be more or less vertical in the chair and the operation be upon the lower jaw, nitrous oxide may not escape so freely, by reason of the tongue being pressed backwards.

E. DANGERS CONNECTED WITH THE ADMINISTRATION

From the physiological and clinical facts to which reference has already been made it is clear that nitrous oxide, when administered in its pure state, and in such a manner that all expirations escape into the surrounding atmosphere, is respirable only up to a certain point. When this point has been reached, oxygen must be admitted to the lungs, otherwise respiration will not proceed. When nitrous oxide is clumsily administered so that the face-piece fails to fit accurately, when more or less re-breathing is permitted, or when the apparatus is faulty in construction, this gas may appear to be con-

tinuously respirable. But when all oxygen is rigidly excluded, and at each inspiration pure nitrous oxide enters the lungs, asphyxial phenomena rapidly supervene, and it is these phenomena, whose occurrence is incidental rather than essential, that have to be taken into account in considering the accidents and dangers to which the patient is liable.

After carefully searching through the medical and dental journals from 1860 to 1900,[1] and instituting inquiries in other directions, the author has only been able to find records of 30 fatalities, and, as will be seen from the subjoined classification, several of these may be excluded. On the other hand, there is every reason to believe that many more deaths have taken place than those which have been reported.

Classified Summary of obtainable Records of Deaths attributed wholly or partly to Nitrous Oxide (1860-1900).

Class A. Deaths undoubtedly due, partly or wholly, to nitrous oxide.

Case 1.—22nd January 1873 : Exeter : F. 38 : stout : enlarged tonsils and uvula : dental operation : semi-recumbent : double administration : asphyxia. Case 2.—27th March 1877 : Manchester : M. middle-aged or elderly : obese : dental operation : double administration : asphyxia. Case 3.—15th September 1883 : London : M. 57 : tongue enlarged by morbid growth and fixed : dental operation : convulsive tremor and rigidity : asphyxial syncope. Case 4.—Reported in 1885 : Paris : M. about 50 : dental operation : "syncope." Case 5.—1st October 1887 : Edinburgh : F. 71 : stout : corsets tight : food in stomach : dental operation : probably asphyxia. Case 6.—1890 : Montreal : M. 24 : dental operation : "syncope." Case 7.—1st May 1892 : Buffalo, U.S.A. : F. : mother of two small children : dental operation : mode of death uncertain. Case 8.—? 1893 : Batley : M. 39 : small and deformed lower jaw : dental operation : asphyxia. Case 9.—1893 : ? place : F. ? age : dental operation : asphyxia, probably favoured by morbid state of upper air-passages. Case 10.—21st February 1894 : London : M. 26 : enlarged tonsils : receding lower jaw : short neck : dental operation : asphyxia. Case 11.—12th January 1895 : Preston : F. 23 : tight corsets : full stomach : dental operation : asphyxia. Case 12.—7th October 1895 : New York : F. 22 : dental operation : ? mode of death. Case 13.—Prior to 1896 : Chestnut Hill : M. ? age : dental

[1] The author is much indebted to Mr. Bellamy Gardner and Mr. Nolan Daly for assistance in this work.

operation : asphyxia. Case 14.—March 1899 : Birmingham : M. 12 : large abscess in base of tongue : fixed lower jaw : horizontal posture : extension of head : opening abscess : asphyxia. Case 15.—Reported to me in 1899 : London : M. 7 : very delicate : old-standing pericarditis and pleurisy : dorsal posture : operation for adenoids : nitrous oxide given with air : head over end of table : syncope : no obstruction in breathing. Case 16.—15th June 1899 : London : F. 27 : food in stomach : operation on elbow : double administration : vomiting : dusky pallor : "syncope." Case 17.—November 1900 : M. 36 : suppuration of neck : left tonsil swollen : incision of neck : nitrous oxide with air first given : then pure nitrous oxide : cessation of respiration : death from asphyxia : at necropsy larynx found to be œdematous.[1]

Class B. Cases in which death is stated to have occurred under nitrous oxide, but of which no particulars are given.

Case 1.—1864 : ? place : young woman : dental operation. Case 2.—About 1868 or 1870 : Louisville. Case 3.—October 1871 : Chicago.

Class C. Deaths doubtfully due, partly or wholly, to nitrous oxide.

Case 1.—12th October 1889 : Philadelphia : M. 46 : dental operation : died with symptoms of apoplexy five hours after administration. Case 2.—? 1864 : New York : M. ? age : lungs much diseased : dental operation : died with pulmonary symptoms two hours after administration. Case 3.—? 1893 : Erie : F. ? age : bad state of health : dental operation : recovery of consciousness : death soon after from "œdema of lungs."

Class D. Deaths due to foreign bodies entering the larynx during or after the inhalation of nitrous oxide.

Case 1.—Before 2nd February 1867 : ? place : M. 13 : dental operation : cork (used as prop) entered larynx : asphyxia. Case 2.—27th April 1882 : Preston : M. 10 : dental operation : molar tooth entered larynx : asphyxia. Case 3.—(*B.M.J.*, 18th February 1899) : tooth entered bronchus : death in twelve days.

Class E. Self-administration.

1893 : London : M. ? age : asphyxia from continued application of face-piece.

---

[1] Lack of time has unfortunately prevented the author from bringing this summary up to date (1906). The following case, however, which occurred in 1904, is worthy of record (*Brit. Med. Journ.*, 17th December 1904, p. 1535). Female æt 18. A cretin. Stature three feet. Scarcely able to move about. Tooth extraction. Convulsive movements. Cessation of respiration. *Post-mortem* : Enlarged thymus : incomplete and thickened mitral valves.

Class F. Deaths wrongly attributed to nitrous oxide.

Case 1.—Before 26th February 1864 : Allentown, Pa. : F. : died a few hours after inhalation. Case 2.—1864 : Swanton Falls, Vt. : F. 17 : died after inhaling nitrous oxide at the hands of a travelling dentist. Case 3.—20th March 1872 : New York : F. : nitrous oxide given, but patient became conscious and dental operation then performed : faintness : vertical posture : fatal syncope.

There are several interesting points in connection with the 17 cases of Class A. Of the first 13 cases, in all of which dental operations were performed, 7 were males and 6 were females. This is an interesting fact, seeing that of the patients who require nitrous oxide for dental operations the great majority are females. The preponderance of males in the table is no doubt dependent upon the greater tendency to dangerous asphyxial spasm in men. The average age of the cases in which the age is given is 33. Perhaps the most interesting and important fact in connection with these deaths is that there was in most of the cases some condition present, before the administration, which rendered the patient liable to a more marked degree of asphyxia than would ordinarily attend an administration of pure nitrous oxide. Thus, in Case 1 the patient, who was stout, had large tonsils, and was anæsthetised in the semi-recumbent posture (see p. 238). In Case 3 the tongue was enlarged and fixed. In Case 5 the patient, who was stout, had tightly-fitting corsets and food in the stomach. In Case 8 the patient had a deformity of the lower jaw. In Case 9 there was post-mortem evidence of a morbid state of the upper air-passages. In Case 10 there were enlarged tonsils, and the patient had a short neck and receding lower jaw. The corsets were tight and the stomach full in Case 11. In Case 14 the air-way was much encroached upon by an abscess in the base of the tongue; in Case 16 the stomach contained food; and in Case 17 one tonsil was enlarged and there was œdema of the larynx. It is thus clear that in at least 50 per cent of the fatalities undoubtedly attributable, wholly or in part, to nitrous oxide, some pre-existing condition was present which rendered the deprivation of oxygen exceedingly hazardous. The large majority of the patients undoubtedly died with

asphyxial symptoms; and it is quite conceivable that, even in those in which the circulation is reported to have failed before the respiration, some unrecognised embarrassment to breathing was present.

It will be convenient to consider the dangerous phenomena which may attend the use of pure nitrous oxide under three main headings: (1) Primary respiratory failure, circulation subsequently ceasing; (2) Primary circulatory failure, respiration subsequently ceasing; and (3) Simultaneous cessation of both respiration and circulation.

(1) **Primary Respiratory Embarrassment and Failure.**—When an **overdose** of nitrous oxide is administered to a healthy subject **(Fourth Degree or Stage)**, the breathing becomes embarrassed and then ceases, the immediate cause of the embarrassment and failure usually being convulsive muscular spasm, anoxæmic in its nature. In certain cases obstructive stertor, of spasmodic origin, may arise whilst the conjunctiva is yet sensitive and the patient not fully anæsthetised, and bring breathing to a standstill. In other cases asphyxial spasm of thoracic and abdominal muscles constitutes the main element in the arrest of breathing. The more vigorous the patient, the more powerful will be the spasm. In tall muscular young men, for example, an opisthotonic state may be induced. Defæcation or micturition may occur. Respiratory failure from paralysis of the nervous mechanism of respiration is rarely if ever met with, at all events in its pure form, in healthy patients subjected to an overdose of this anæsthetic. At the moment when breathing ceases the colour is usually markedly cyanotic or livid, the eyeballs generally turned upwards, the lids separated, and the pupils widely dilated. The character of the pulse at this juncture will depend upon circumstances. For example, should obstructive stertor have come on rather earlier than usual, and be the immediate cause of arrested breathing, the pulse may show but slight evidences of depression. But should more of the anæsthetic have been introduced before breathing ceases, the pulse will probably be quick and small at the moment of the arrest. Under any circumstances, however, the condition induced by an overdose, in patients with a good circulation, is one of primary respiratory failure.

The length of time the heart will hold out against such asphyxial symptoms will depend upon its previous condition. Experience shows that in the case of young and vigorous subjects a comparatively long period of suspended breathing elapses before the heart's action becomes seriously depressed; whereas, in debilitated or flabby patients, with dilated, fatty, or feeble hearts, any marked interference with respiration will much more quickly lead to final cardiac arrest.

Patients with any **pre-existing narrowing or abnormality of the upper air-passages** are particularly prone to pass into a state of dangerous asphyxia when nitrous oxide is pushed to its fullest extent. This is well exemplified by the fatal cases to which reference has been made, and also by Illustrative Case No. 44, p. 538, a case in which the author was obliged to perform tracheotomy in order to resuscitate the patient. Elderly obese subjects are liable to pass into a state of completely obstructed breathing, by reason of the engorged tongue being spasmodically drawn towards the pharyngeal wall. Patients with enlarged tonsils, adenoid growths, etc., are similarly liable to obstructed breathing.[1] The numerous other conditions capable of favouring primary respiratory failure are elsewhere fully considered (p. 164 *et seq.*).

As already mentioned (p. 252) the performance of an operation during partial anæsthesia may reflexly suspend breathing, and under certain conditions this reflex arrest of respiration may assume such proportions as to constitute what has been termed **respiratory shock.**

The passage of foreign bodies into the larynx, trachea, or bronchi during nitrous oxide anæsthesia may set up asphyxial symptoms of a grave or fatal character (see p. 539).

(2) **Primary Circulatory Depression or Failure.**—There is every reason to believe that in moderately healthy subjects nitrous oxide is incapable of producing symptoms of circulatory depression except as a sequel to respiratory embarrassment. For more than 20 years the author has kept careful notes of every interesting or abnormal case of anæsthesia, and,

[1] Probably in this category should come two fatal cases reported in the *Lancet*, 13th Feb. 1904, p. 439, and 14th Nov. 1903, p. 1368. In both these cases enlarged cervical glands were present.

on looking through his notes, he is unable to find a single instance of primary pulse failure wholly dependent upon the action of this gas.

It has been alleged that there is a grave risk of cardiac syncope from the performance of surgical operations, and particularly dental operations, upon patients imperfectly anæsthetised by nitrous oxide. But when we consider that hundreds, and possibly thousands, of persons are daily subjected to dental operations whilst in the first or second degree of anæsthesia, it is probable that the risk of syncope from this cause has been overestimated. That reflex circulatory effects may arise when patients are emerging from nitrous oxide anæsthesia and the operation is still in progress, in other words, that patients may become "faint" from the distinct perception of pain, is probable. But if consciousness be in abeyance, there is every reason to believe that surgical stimuli are incapable of depressing the circulation, at all events to any dangerous degree. In nearly every recorded nitrous oxide death some disturbance of breathing appears to have been present; and it is in the highest degree probable that, in many of the dangerous and fatal cases in which the symptoms have been regarded as primarily cardiac or circulatory, some undetected asphyxial factor has been present.

(3) **Simultaneous Depression or Failure of Respiration and Circulation.**—This condition is fortunately very rare. It is most likely to arise in patients with valvular or other forms of cardiac disease. Instead of the circulation being well maintained up to the point at which anoxæmic spasm or stertor arises, the pulse becomes feeble or imperceptible, a bluish pallor is observed, and the respiration, instead of being stertorous or jerky, is markedly shallow. There is apparently a direct relation between the feeble circulation and feeble breathing. Given that the general circulation is satisfactory, the anoxæmic state induced by nitrous oxide leads to excessive rather than to diminished discharges from the respiratory centre. But when, from any particular cause, such as the presence of valvular or other cardiac disease, the cerebral circulation becomes defective, the respiratory centre appears to be more affected by the deficiency than by the quality of the

blood which reaches it, and it hence happens that the breathing becomes shallow, without stertor or spasm. The author has never seen this condition become so grave as to threaten life; although it is quite obvious that it might do so. In Case 15, Class A of the above group, the patient was the subject of an adherent pericardium and old-standing pleurisy—two conditions which would certainly render the administration of nitrous oxide somewhat hazardous. In this particular case, the author is informed on good authority that death occurred without any indications of obstruction.

Post-mortem Appearances.—The post-mortem appearances after death under nitrous oxide will naturally depend upon the presence or absence of pathological conditions during life, and upon the precise mode of death.

In seven of the cases included in Class A in the above list post-mortem records are available. Speaking generally, these records point to death by asphyxia. As a good example of the usual appearances, those found in Case 2 may be studied.[1] The cerebral membranes were distended with serous fluid, the cerebral veins intensely congested, and the cerebral ventricles full of fluid; the lungs were very dark and intensely congested; the right side of the heart was full of dark fluid blood, and the left side empty. In Case 3 each ventricle contained a little blood; the auricles were empty; and there were pulmonary and renal congestion. In Case 8 the right side of the heart was full of dark fluid blood; the heart substance was flabby and fatty; the lungs, brain, and kidneys were congested. In Case 9 the ventricles were firmly contracted; there was a dark clot in the mitral valve; the lungs and spleen were congested. In Case 10 all cavities of the heart were empty, except for a small quantity of fluid blood in the right ventricle; the veins of the chest were all full of dark fluid blood; the lungs were engorged and nearly airless; and there was venous engorgement of the cerebral hemispheres. In Case 15 there were considerable pericardial adhesions; the heart had undergone slight fatty degeneration; and the left pleural cavity was obliterated by adhesions. In addition to the details here given, there were in many of the cases certain pathological states, such as enlargement of tonsils, catarrhal and œdematous conditions in different parts of the air-passages, enlargement of bronchial glands, etc. These states, however, are of interest as *predisposing* causes of the asphyxial seizure.

It must be borne in mind in considering post-mortem appearances (1) that differences in the method of performing

[1] *Lancet*, vol. i., 1877, p. 544.

autopsies may of themselves introduce differences in the appearances observed; and (2) that artificial respiration, inversion, and other movements to which the body may have been subjected immediately after death, may alter the conditions of the great vessels, heart cavities, and lungs, more particularly as regards the quantities of blood contained within these parts at the actual moment of dissolution.

F. AFTER-EFFECTS

For reasons which have already been given, the administration of pure nitrous oxide is necessarily exceedingly short, and it hence happens that disagreeable after-effects are generally completely absent. **Transient giddiness or headache** occasionally occurs; and **lassitude or sleepiness** may be experienced. Although the presence of undigested food within the stomach is not necessarily followed by vomiting, it is nevertheless important that attention should be paid to the diet (see p. 226). Some patients invariably suffer from **nausea** or even actual vomiting after nitrous oxide; but such cases are very exceptional. So-called "bad travellers" are often thus affected. A double administration of the gas with an interval of consciousness is liable to lead to after-sickness, especially in dental practice. When re-breathing has been practised, recovery will not take place quite so rapidly as usual, and headache and nausea may be thus initiated. Headache unattended by nausea sometimes follows the administration when food is present in the stomach. Should blood be swallowed during or after the operation, after-sickness will be likely to follow.

Feelings of faintness are, as a general rule, dependent upon some gastric disturbance brought about by the administration. Such feelings are, as will be gathered from what has just been said, most common when the diet has not been properly regulated. **Hysterical outbursts**, or transient states of hallucination and struggling, are sometimes met with after the administration of nitrous oxide, but are very exceptional. **Protracted stupor, cataleptic states, hemiplegia,**[1] and even

[1] A curious case is reported by Dr. Ashford (*Amer. Journ. Med. Scien.*, New Series, vol. lvii., 1869, p. 408). A girl of sixteen became insensible for two

insanity[1] have one and all followed the administration; but such sequelæ are exceedingly rare. **Temporary glycosuria** and even true **diabetes**[2] are also said to have been produced by the inhalation of nitrous oxide; but the evidence in favour of such charges cannot be regarded as conclusive. **Retinal hæmorrhage**, from intense venous engorgement, has been known to occur under the influence of pure nitrous oxide.[3]

Section II.—The Administration of Definite Mixtures of Nitrous Oxide and Air

A careful study of the phenomena resulting from the administration of nitrous oxide with definite proportions of atmospheric air is obviously essential before we can discuss the use of this anæsthetic with unknown proportions of air. It is therefore proposed, in this section, to give a brief summary of the results which the author obtained in the course of the investigation referred to on p. 278. As will be pointed out in the following section, it has been customary, ever since the anæsthetic properties of nitrous oxide became generally recognised, to administer this agent in conjunction with atmospheric air, more particularly with the object of maintaining insensibility for prolonged surgical operations; but, so far as the author is aware, no cases have been recorded in which definite mixtures of nitrous oxide and air have been administered.

A specially made gasometer (Fig. 26) was employed by which any desired percentages of nitrous oxide and of air could be administered. The following administrations were conducted, carefully timed, and recorded:—

hours after the exhibition of nitrous oxide. Headache, dizziness, and left hemiplegia followed. Dr. H. C. Wood also refers to another case (*Brit. Med. Journ.*, 16th Aug. 1890, p. 385) which occurred in Philadelphia: "A gentleman arose from the dentist's chair after an inhalation of nitrous oxide, staggered, and fell in an apoplexy."

[1] See an interesting paper by Dr. Savage, "Insanity following the Use of Anæsthetics in Operations" (*Brit. Med. Journ.*, 3rd Dec. 1887, p. 1199), in which is mentioned the case of a young woman, a chronic alcoholic, liable to hysterical attacks, who, after the extraction of teeth under nitrous oxide gas, was attacked by delirious mania, which lasted for three weeks and terminated in dementia. Dr Savage regards the anæsthetic as the immediate cause of the attack.

[2] See *Brit. Med. Journ.*, 16th August 1890, p. 385.

[3] Sir John Tweedy informs the author that he has seen a case of this kind. The hæmorrhage was extensive and "about the posterior pole of the fundus."

				Cases.
Nitrous oxide with	3	per cent air	.	5
,, ,,	5	,,	.	10
,, ,,	6	,,	.	6
,, ,,	7	,,	.	6
,, ,,	10	,,	.	10
,, ,,	12	,,	.	5
,, ,,	14	,,	.	4
,, ,,	15	,,	.	9
,, ,,	16	,,	.	5
,, ,,	18	,,	.	12
,, ,,	20	,,	.	7
,, ,,	22	,,	.	14
,, ,,	25	,,	.	8
,, ,,	30	,,	.	4
,, ,,	$33\frac{1}{3}$	,,	.	1
				106

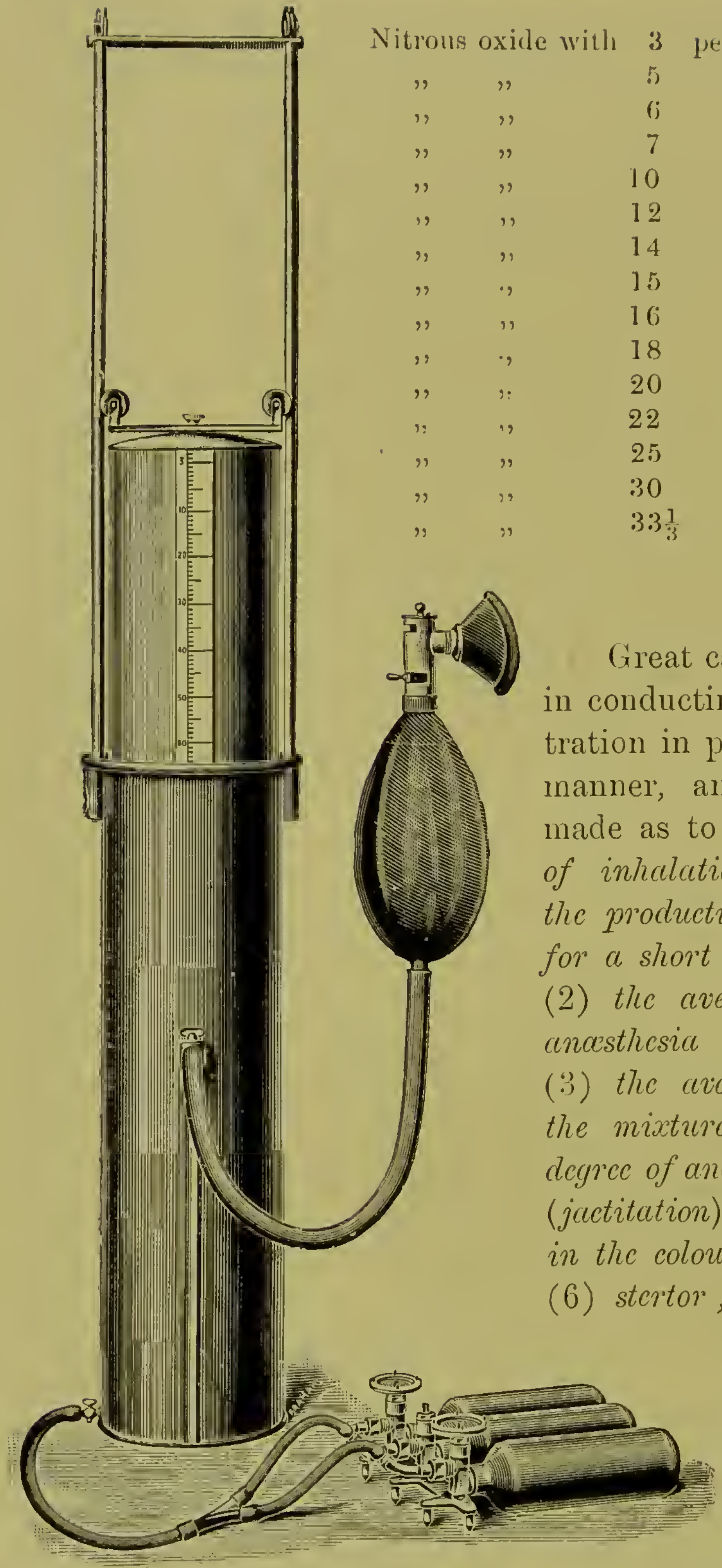


FIG. 26.—Specially constructed Gasometer by which definite mixtures of Nitrous Oxide and Air and of Nitrous Oxide and Oxygen were administered.

Great care was exercised in conducting each administration in precisely the same manner, and records were made as to (1) *the duration of inhalation necessary for the production of anæsthesia for a short dental operation*; (2) *the average duration of anæsthesia after inhalation*; (3) *the average quantity of the mixture used*; (4) *the degree of anoxæmic convulsion (jactitation)*; (5) *alterations in the colour of the features*; (6) *stertor*; (7) *phonation*; (8) *reflex and excitement movements*; and (9) *after-effects*.

It was found that anæsthesia could be obtained with mix-

tures of nitrous oxide and air, provided the latter did not exceed 30 per cent. With $33\frac{1}{3}$ per cent the author failed to induce complete unconsciousness. With small percentages of air the symptoms were practically identical with those produced by the pure gas. The greater the proportion of air, the longer was the inhalation period before symptoms of anæsthesia appeared. Thus with 3 per cent and 5 per cent of air the average inhalation period was 69 secs.; with 30 per cent of air it was 148 secs. The duration of available anæsthesia for an intra-oral operation was distinctly longer than after nitrous oxide alone. The shortest anæsthesia was met with when employing 3 per cent of air (30·8 secs.) and 30 per cent of air (29·7 secs.), *i.e.* at the two extremes; the longest average anæsthesia being recorded with 14 per cent, 16 per cent, and 22 per cent of air, the respective durations with these percentages being 40·5 secs., 42 secs., and 42·6 secs. It is an interesting fact that there was more anoxæmic convulsion with 3 and 5 per cent of air than with pure nitrous oxide, the explanation being that, in the absence of all oxygen, obstructive stertor comes about so quickly as to cut short the intake of the anæsthetic gas before the blood has become sufficiently altered to induce any marked convulsive seizure. With higher percentages of air the anoxæmic muscular phenomena progressively lessened, disappearing altogether with 30 per cent of air. With moderate percentages of air the clonic movements were but feebly marked. Like anoxæmic convulsions, lividity and cyanosis were more evident with small percentages of air than with pure nitrous oxide, and for the same reason. With 30 per cent of air there was but little alteration in the normal colour. The tendency to stertor progressively lessened as the percentages of air rose. With mixtures poor in air the stertor was coarser and more irregular than with those containing moderate percentages. Very interesting changes in the type of stertor were observed as the percentages of air increased. There was somewhat less phonation during dental operations performed under nitrous oxide mixed with small percentages of air than under nitrous oxide itself; but with mixtures containing more than 10 per cent of air phonation was common. Reflex and

excitement movements were, on the whole, less marked than with pure nitrous oxide; and this was especially noticeable with moderate percentages, for with such percentages the best types of anæsthesia were attainable. So far as the general results of these cases are concerned, the investigation showed that with percentages of air between 14 and 22 a very distinct improvement was manifest over the ordinary nitrous oxide cases. With percentages below 14 and above 22 the improvement in general results was less marked. The conclusion at which the author arrived in the course of this investigation was that the best definite mixture for men was one containing from 14 to 18 per cent of air, whilst the best for women and children was one containing from 18 to 22 per cent of air.

The author is not aware that administrations of nitrous oxide and air, thus accurately mixed, have been conducted upon any large scale in our hospitals; but it seems to him that it would be worth while to employ such mixtures in preference to pure nitrous oxide. The chief drawback of the system undoubtedly is the necessity for large gasometers.

Section III.—The Administration of Nitrous Oxide with indefinite Quantities of Air

The effects produced by administering nitrous oxide with indefinite quantities of air will necessarily depend upon numerous circumstances. The most important of these is the proportions existing between the various gases inhaled. Putting on one side for the moment all plans of administration in which re-breathing is possible, and taking it for granted that the gases presented to the lungs are inspired and expired through accurately working valves and through orifices of sufficiently large calibre, it may be said that there are two systems by which nitrous oxide may be administered with indefinite quantities of air. In the first of these the anæsthetist administers the pure gas as already described, till his patient is partially or completely anæsthetised; he then admits one or more breaths of air by turning the stopcock; and he continues to thus alternately administer nitrous oxide and

air till (as in general surgery) the operation is completed, or till (as in oral or nasal surgery) sufficiently deep anæsthesia has been induced. In the second system of conducting the administration the anæsthetist aims at administering nitrous oxide and air concurrently rather than alternately, and with this object he employs some simple expedient or contrivance which will, from the commencement to the end of the administration, allow of sufficient air gaining access to the lungs to obviate any marked asphyxiation from the nitrous oxide. In actual practice these systems are often combined or used indiscriminately—the patient at one moment breathing pure nitrous oxide, at another nitrous oxide mixed with air, and at another air itself.

Should to-and-fro breathing be permitted during any part of a gas-and-air administration, a more complex result than that obtainable when accurately working valves are present will necessarily ensue, for instead of the excreted carbonic acid escaping as it would under ordinary circumstances, it is intercepted, so to speak, in the inhaling bag, and its quantity will progressively increase within that bag so long as to-and-fro breathing is permitted. Moreover, the quantity of this respiratory product present in the bag at any given moment will depend upon the extent to which air has been admitted with the nitrous oxide (see p. 48).

From time to time during the last thirty years, and particularly in the United States, cases have been recorded in which general surgical operations, varying in duration from a few minutes to an hour or longer, have been performed under nitrous oxide administered in one or other of the ways just described; and in this country Clover and others have chronicled similar results. The first systematic endeavour to administer nitrous oxide and air *concurrently* appears to have been made by Dr. George Brush of Brooklyn,[1] who employed an apparatus with a sliding valve which could be so arranged as to admit atmospheric air according to the needs of the patient. Operations lasting upwards of an hour were performed under the influence of anæsthesia thus produced. But there is little to be said in favour of such a line of practice,

[1] *Brooklyn Med. Journ.*, May 1890.

save perhaps for very exceptional cases; for the resulting anæsthesia is liable to be uneven and unsatisfactory in its type, owing to the physical characters and peculiar physiological action of this anæsthetic. Had we no better means at our disposal for inducing and maintaining anæsthesia, we should have to be content with the results thus obtainable; but as compared with the anæsthesia of ether or chloroform that which thus results from the inhalation of pure nitrous oxide and air cannot be regarded with favour. At the same time there are undoubtedly certain special cases in which the use of this system is distinctly advantageous. For example, when an anæsthesia of from one to five or ten minutes is needed, when absolute immobility and complete muscular relaxation are not essential, and when there is some special reason for avoiding ether or chloroform, this plan of anæsthetisation may be employed. It certainly has the great merit that it is rarely followed by after-effects; but it cannot be recommended when deep anæsthesia, in our modern sense, is essential to success; nor can it be regarded as appropriate for all types of subjects. As already pointed out, there are numerous patients in whom the asphyxial condition incidental to many methods of anæsthetising must be studiously avoided, and although it is theoretically possible to obtain a non-asphyxial anæsthesia by this system, such an anæsthesia is not always obtainable.

In conducting the administration of nitrous oxide and air for an ordinary surgical operation, the anæsthetist may either adopt the *alternate* plan, or, by keeping the air-hole of the stopcock slightly open, he may *concurrently* administer the nitrous oxide and air. The longer the administration has proceeded, the larger may be the quantity of air allowed. By carefully watching the patient's symtoms, the precise junctures at which the change from nitrous oxide to air should be effected, or at which more air should be allowed, will be readily ascertained. An endeavour must be made to maintain a snoring, regular breathing, with moderate duskiness.

As nitrous oxide is unquestionably of special utility in dental surgery, it is not surprising that a great deal of attention has been directed towards improving the methods of administer-

ing this anæsthetic for the extraction of teeth. Not only have attempts been made to improve the *type* of anæsthesia, but many ingenious devices have been proposed for *prolonging* the insensibility ordinarily produced. Although, as will be presently shown, the best form of anæsthesia is attainable only when oxygen (and not atmospheric air) is mixed with the nitrous oxide, "gas-and-air" anæsthesia is distinctly preferable to that produced by nitrous oxide alone. This has been specially pointed out by Mr. George Rowell.[1] When from ten to twenty breaths of the pure gas have been taken, Mr. Rowell admits one breath of air, and subsequently repeats this procedure about every fifth breath. A longer and better form of anæsthesia results than when pure nitrous oxide is continuously inhaled. In the majority of cases a commencing irregularity in breathing without either stertor or muscular twitching is the sign that proper anæsthesia has been induced.

With regard to the prolongation of anæsthesia for protracted dental operations, the first attempt appears to have been made by Clover and Coleman, who devised and used a nose-piece through which the administration of the gas was kept up. The next step in this direction was taken by Mr. S. Coxon,[2] who, after inducing anæsthesia in the ordinary way, places a metal tube in the mouth and keeps up a supply of "gas" during the operation. It is advisable, according to Dr. McCardie,[3] to close the anterior nares when employing a mouth-tube, and if this be done, anæsthesia of several minutes' duration may be obtained. Mr. Harvey Hilliard[4] induces anæsthesia in the customary manner, and then maintains it by means of a soft tube passed through the anterior nares into the naso-pharynx. The late Mr. Alfred Coleman[5] successfully revived the use of the nose-piece; and working upon Mr. Coleman's suggestions, Mr. Herbert Paterson[6] has obtained results which are certainly satisfactory from many points of view.

[1] See *Journ. Brit. Dent. Assoc.*, 15th October 1892, p. 669.
[2] *Clinical Journal*, 1st June 1898, p. 116.
[3] *Ibid.*, 29th March 1899, p. 37.
[4] *Lancet*, 28th June 1902.
[5] *Clinical Journal*, 25th May 1898, p. 92.
[6] *West London Medical Journal*, July 1899.

By working the foot-key of a nitrous oxide cylinder,[1] the liberated gas is made to enter a small bag, to which is attached a two-way stopcock (Fig. 27). From this stopcock a couple of tubes pass to supply a metal nose-piece, fitted with a rubber air-pad to allow of accurate adaptation. The bag having been *nearly* filled with "gas," a mouth-prop is inserted, the nose-piece *carefully* adjusted, and the stopcock turned on. A stream of "gas" now passes into the nasal passages during each inhalation. The patient thus breathes nitrous oxide through the nose, and a variable amount of air through the mouth. As anæsthesia approaches, the breathing as a rule becomes entirely nasal, practically no air gaining access through the mouth. After the first few breaths it may be necessary to slightly distend the bag. The operation is commenced in about 40 seconds. The anæsthesia can be maintained as long as is desired, but it is necessary to turn off the stopcock about once in every four or five breaths, so as to allow the patient to obtain a breath of air through the aperture in the stopcock (H). Only the slightest degree of duskiness is necessary, stertor and cyanosis being avoided by giving sufficient air. In addition to the nose-piece, there is an independent celluloid mouth-piece fitted with one (expiratory) valve. This may be required when, as occasionally happens, there is difficulty in establishing nasal breathing; or

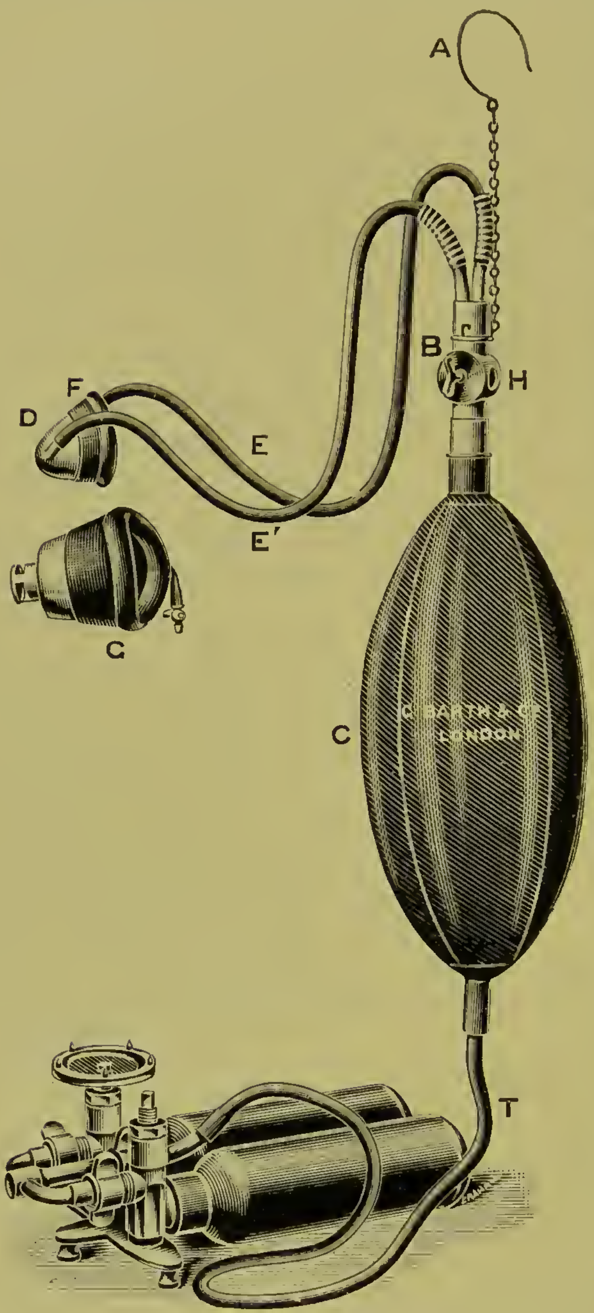


FIG. 27.—Paterson's Apparatus for administering Nitrous Oxide for Prolonged Operations within or about the Mouth.

[1] I am indebted to Mr. Paterson for this description.

it may be needed to shorten the period of induction. With the mouthpiece anæsthesia is obtained in 15 or 20 seconds. In the majority of cases its use is not required, and from the patient's point of view it is undesirable, as the administration is more pleasant without it. From 8 to 10 gallons of gas are required for an ordinary administration. Anæsthesia can be maintained for 10 minutes with from 25 to 30 gallons of gas.

The results obtained by this and other methods of prolonging nitrous oxide anæsthesia for dental operations are, from the patient's point of view, remarkably satisfactory; for not only may an absolute immunity from pain be secured for three, four, or five minutes, or even longer, but disagreeable after-effects are rarely met with. The type of anæsthesia, however, can hardly be regarded as satisfactory in the modern sense; and in order that the best results may be obtained, a third person—that is to say, some one in addition to the surgeon and the anæsthetist—is needed to steady the patient, insert and adjust the Mason's gag, and sponge out blood, etc.

Kirkpatrick[1] has modified Paterson's apparatus by introducing an expiratory valve in connection with the nose-piece. This valve can be thrown out of action when desired. The results in 490 cases are described as highly satisfactory, the longest period of anæsthesia obtained being seventeen minutes.

Section IV.—The Administration, at Ordinary Atmospheric Pressures, of Definite Mixtures of Nitrous Oxide and Oxygen

From what has been said in the preceding sections of this chapter it is clearly possible, by the simple dilution of nitrous oxide with air, to more or less completely prevent lividity, tumultuous breathing, and jactitation, without interfering with anæsthesia. But there is one formidable objection to the use of air as an oxygenating agent, viz. that it contains such a large percentage of nitrogen. Although this latter gas, when given alone, will produce anæsthesia by excluding oxygen,[2] it cannot in any way contribute towards nitrous oxide anæsthesia in the presence of that percentage of oxygen which is capable of preventing cyanosis and clonic muscular spasm. If we

[1] *Medical Press*, 16th July 1902.
[2] The reader is referred to p. 456 *et seq.*, where he will find details of several cases in which the author administered nitrogen for tooth extraction.

administer with nitrous oxide a percentage of air which will prevent lividity and the other symptoms referred to, we shall, in most cases, also prevent deep anæsthesia, owing to the small percentage of nitrous oxide which would be possible in such a mixture. For example, a mixture of 40 per cent of air and 60 per cent of nitrous oxide would contain about 8 per cent of oxygen and about 32 per cent of nitrogen; and although the 8 per cent of oxygen would be sufficient to nearly or completely preserve the natural colour of the patient's face, and to suppress clonic muscular spasm, the 60 per cent of nitrous oxide would be insufficient to produce tranquil anæsthesia. If, however, instead of using air for oxygenating purposes, we employ oxygen, we shall be able to replace the 32 per cent of useless nitrogen by a corresponding quantity of useful nitrous oxide, and the proportion of the latter will now rise to 92 per cent. With such a large percentage of nitrous oxide, anæsthesia is certain to become established, and the percentage of oxygen remaining the same as in the nitrous oxide-and-air mixture, cyanosis and other evidences of diminished blood oxygenation will be prevented. These few considerations will act as a link to connect the preceding with the present section.

As already mentioned (p. 96), Dr. E. Andrews of Chicago was the first to employ oxygen in conjunction with nitrous oxide, and to obtain a non-asphyxial form of anæsthesia by this means. It was not, however, till ten years later, when Paul Bert published his interesting observations, that this system of anæsthetisation began to attract attention. Bert's researches led him to regard nitrous oxide as an agent which, as customarily given, could only produce anæsthesia when administered pure, *i.e.* free from air or oxygen. He came to the conclusion that, whilst it was desirable to avoid all asphyxial phenomena by mixing oxygen with nitrous oxide, it was impossible to produce anæsthesia by such a mixture without increasing the atmospheric pressure (see p. 303). But in spite of Bert's views it soon became clear from the observations of Klikowitsch,[1] Winckel, Döderlein, Zweifel, Hillischer, and the author, that such an increase, although it was doubtless capable of in-

[1] For references to the works of these observers, see the author's book on *The Administration of Nitrous Oxide and Oxygen for Dental Operations*, p. 10.

tensifying the effects, was not absolutely necessary for the production of anæsthesia.

Before proceeding to the consideration of Bert's results (Section V.), and to the description of the best means for producing non-asphyxial nitrous oxide anæsthesia at ordinary pressures (Section VI.), it is proposed to give a brief summary of the results at which the author arrived when administering various definite mixtures of nitrous oxide and oxygen.

In the course of this investigation[1] the following administrations were conducted:—

					Cases.
Nitrous oxide	with	3	per cent	of oxygen	5
,,	,,	4	,,	,,	10
,,	,,	5	,,	,,	17
,,	,,	6	,,	,,	11
,,	,,	7	,,	,,	11
,,	,,	8	,,	,,	18
,,	,,	9	,,	,,	5
,,	,,	10	,,	,,	10
,,	,,	11	,,	,,	7
,,	,,	13	,,	,,	2
,,	,,	20	,,	,,	4
					100

As in the "gas and air" cases, these mixtures were accurately prepared and accurately administered under precisely similar circumstances, by means of an apparatus with accurately working valves, great care being taken to exclude the minutest proportions of atmospheric air. Records were made with regard to the various points referred to on p. 295. The duration of inhalation necessary for the performance of a dental operation increased as the percentage of oxygen rose, that is to say, a shorter inhalation was necessary with small percentages of oxygen than with large. For example, with 3 per cent of oxygen the average inhalation period was 96·6 seconds; whereas with 20 per cent of oxygen it was 223·5 seconds. There was a very marked contrast between the short inhalation period of pure nitrous oxide (56 seconds) and that of mixtures of nitrous oxide and oxygen. It is interesting to note that deep anæsthesia was obtainable even when the proportion of oxygen

[1] See footnote, p. 278.

was as great as that in atmospheric air. With regard to the duration of anæsthesia after inhalation, this was distinctly longer than when mixtures of nitrous oxide and air were employed, just as the anæsthesia with these latter mixtures was greater than when pure nitrous oxide was used. Thus, the lowest average anæsthesia (39·7) was very little below the highest (42·6) of the air cases. The best results, so far as a lengthy available anæsthesia was concerned, were met with when using 7 per cent of oxygen, the average duration of anæsthesia after inhaling nitrous oxide mixed with this percentage of oxygen being 50·1 seconds. A very interesting result of the investigation was to show that anoxæmic convulsions were readily prevented, even by small percentages of oxygen. During the inhalation of nitrous oxide, either pure or with oxygen up to 4 per cent, some degree of anoxæmic convulsion is very common. But when once 5 per cent of oxygen is reached, very little convulsive movement is observed, and with 6 per cent and over there is no such movement visible. The anoxæmic convulsion of pure nitrous oxide becomes progressively attenuated and weakened, so to speak, as the proportion of oxygen mixed with the anæsthetic gas increases. With regard to alterations in the patient's colour, the author found that with less than 11 per cent of oxygen some degree of lividity was present; but with this percentage and over, the normal colour was retained. With 8, 9, and 10 per cent of oxygen the alteration was very slight. With smaller percentages the lividity was of course greater. The effects of even small percentages of oxygen in preventing stertor were very marked. Thus, with 3, 4, and 5 per cent of oxygen the ordinary stertor of pure nitrous oxide loses its irregular character, and becomes replaced by a regular, snoring sound, similar in its type to that of ether or chloroform. With somewhat higher percentages of oxygen, snoring becomes less pronounced. With 20 per cent of oxygen the snoring altogether vanishes. Phonated sounds are far less common under nitrous oxide and oxygen than under nitrous oxide and air. They are most likely to arise with very small or with very large percentages. Reflex and excitement movements are uncommon with small percentages of oxygen; but are likely to assert

themselves, and possibly to become inconvenient, when the percentage of oxygen rises to 10 per cent or more. Stamping, kicking, side-to-side movements, etc., are very common with from 10 to 20 per cent of oxygen. As regards the general result: the best mixtures for adult males were those containing 5, 6, or 7 per cent of oxygen; and mixtures containing 7, 8, or 9 per cent were best for females and children.

The chief drawbacks to the use of definite mixtures of nitrous oxide and oxygen are—(1) that they are difficult to prepare with accuracy and in sufficient quantities; (2) that different subjects require different percentages; and (3) that the proportion of oxygen cannot be increased or decreased to meet special conditions arising during the administration. At the same time it is interesting to know what phenomena are associated with different percentages; for it is only upon a basis of this kind that we can successfully administer nitrous oxide and oxygen for protracted operations (see p. 313).

Section V.—The Administration, under increased Atmospheric Pressures, of definite Mixtures of Nitrous Oxide and Oxygen (Paul Bert's Method)

The following extract from the writings of Paul Bert will express the views which he held:[1]—

My experiments have demonstrated that, in an animal breathing pure nitrous oxide, when anæsthesia is established, 100 volumes of arterial blood contain 45 volumes of nitrous oxide. If, then, we introduce into the blood 45 volumes of nitrous oxide for every 100 volumes of blood, we shall obtain anæsthesia. Now, when pure nitrous oxide is contained in a bag under ordinary pressure this gas is at the tension of 100. But if the bag of gas is placed in an air-tight chamber, the pressure in which is raised to two atmospheres, the tension of the gas in the bag will be 200. And if this bag within the air-tight chamber, instead of containing 100 per cent of nitrous oxide, viz. this gas in a state of perfect purity, contain only 50 per cent, the tension of this 50 per cent of nitrous oxide will be equal to 100, that is to say, the quantity of nitrous oxide will be exactly that which is necessary to induce anæsthesia. The other 50 per cent can therefore be occupied by another gas for sustaining life, viz. oxygen, and

[1] *Progrès Médical*, No. 9, 1880. See also *Traité d'Anesthésie Chirurgicale*, by J. B. Rottenstein, Paris, 1880, p. 303.

it will therefore be possible to carry out prolonged operations. I have chosen these figures to render the explanation of the method at which I have aimed more intelligible. But they must not be considered as indicating the proportions of the oxygen and nitrous oxide to be employed. The proportion of oxygen would be too high,—in fact, we know that air contains only 21 per cent. The problem therefore resolves itself into a very simple calculation. By mixing 85 parts of nitrous oxide with 15 parts of oxygen it is only necessary to raise the pressure to 89·5 cm. Supposing the barometric pressure to be 76 cm., an extra pressure of only 13·5 cm. of mercury is required to induce anæsthesia. Under these conditions the animal operated upon soon falls asleep and into deep anæsthesia. The circulation and respiration are in no way influenced by the nitrous oxide, though the perceptive faculties are suspended, and if the quantity of the gaseous mixture inhaled by the animal is sufficient, it is possible to maintain the most absolute anæsthesia for several hours.

After a series of satisfactory experiments upon lower animals, Bert put his theory to a practical test. He had constructed for him a metal chamber (Fig. 28) in which the atmospheric pressure could be raised to the desired extent. The chamber was large enough to contain several persons. A mixture of 85 per cent of nitrous oxide and 15 per cent of oxygen was administered to a patient, and an extra pressure of 13·5 cm. (*i.e.* a total pressure of 89·5 cm.) was employed. The first operation during nitrous oxide and oxygen anæsthesia under pressure was performed by M. Léon Labbé on 15th February 1879. An in-growing toe-nail was painlessly removed during tranquil anæsthesia free from all traces of asphyxia. On 20th March 1879, M. Péan amputated a leg with equal success. Numerous other operations were performed. In the large majority of cases anæsthesia is said to have been of the most perfect type. There was no alteration of colour, the breathing was tranquil, and the pulse good and regular. In a few cases, however, excitement and nausea were noted.

Fig. 28 shows the chamber which M. Claude Martin of Lyons has used successfully.[1] The following are its chief parts:—A, Air-tight metal chamber with windows. B, Sliding doors. C, Arrangement for introducing anything into chamber without lowering internal pressure. D, Canvas bag for holding the mixed gases. E, Tap through which the mixture passes to inhaling apparatus. F,

[1] M. Martin has very kindly given me permission to reproduce this figure. The reader will find much interesting information in M. Martin's pamphlet, *De l'Anesthésie par le Protoxyde d'Azote avec ou sans tension*, 1883.

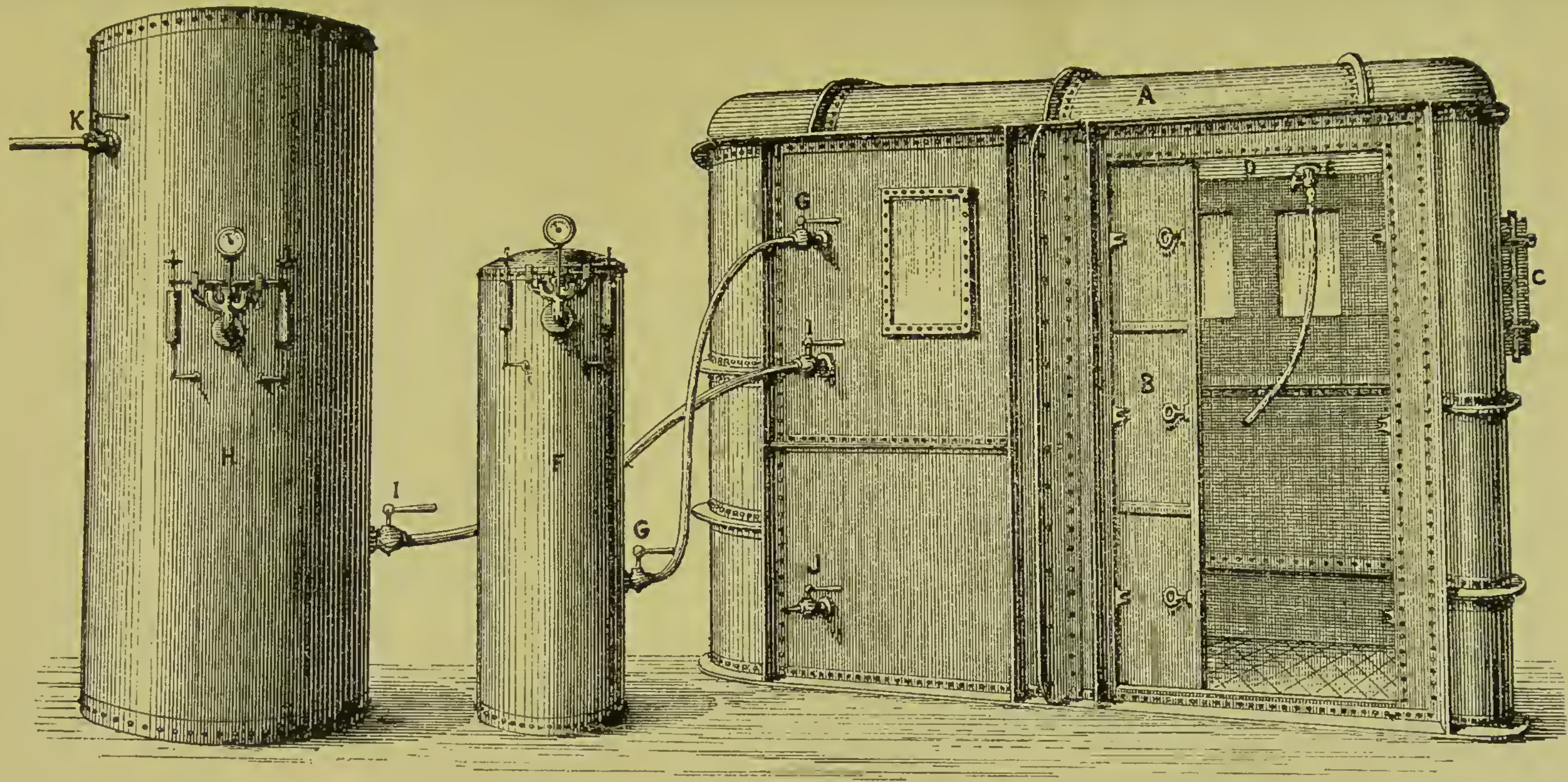


Fig. 28.—Air-tight Chamber for the Administration of Nitrous Oxide with Oxygen under increased Atmospheric Pressure (Paul Bert's Method).

Receiver containing mixed gases under greater pressure than that inside chamber. G, G, Taps through which the mixed gases pass to the bag inside the chamber. H, Intermediate receiver for compressed air charged prior to the administration through the tap K. By using this intermediate receiver the compressed air which has been warmed by the action of the pumps is allowed to cool, and can be transmitted to the chamber when required through the taps I, I. J, Tap for lowering pressure in chamber, should occasion require. M. Martin found that he obtained the best results when working with percentages and pressures somewhat different to those advocated by Paul Bert. He used 88 per cent of nitrous oxide with 12 per cent of oxygen, and maintained an atmospheric pressure within the chamber of 110 cm. With the percentages and pressure recommended by Paul Bert he met with considerable excitement, which led him to modify the details of the method.

It is unnecessary to further describe Paul Bert's method. The apparatus is, as will be gathered from the drawing, too complicated, too costly, and too cumbrous to allow of its being widely used. The author is informed, too, on good authority, that the increased pressure within the chamber not unfrequently produces considerable discomfort to those engaged in the operation.

The question naturally arises: Is the anæsthesia thus obtained more satisfactory in its type than that which can be secured by administering these two gases together, in proper proportions, at ordinary atmospheric pressures, and by varying the percentage of oxygen to meet the special circumstances of each case? That an increase in atmospheric pressure is serviceable in preventing or treating excitement has been proved by those who have employed Bert's method—notably by Dr. C. Martin of Lyons; but, until further experiments have been made, it is difficult to say whether, at ordinary atmospheric pressures, such excitement cannot equally well be avoided or allayed by decreasing the proportion of oxygen in the mixture.

Section VI.—The Administration, at Ordinary Atmospheric Pressures, of Nitrous Oxide with Varying Proportions of Oxygen

The first successful attempt to administer nitrous oxide and oxygen at ordinary atmospheric pressures by means of an

apparatus capable of regulating the proportions of the two gases was made by Hillischer[1] of Vienna; and it was the report of his work that first directed the author's attention to the subject. In 1886 the author commenced a series of experimental administrations at the Dental Hospital of London; he tried a large number of different methods of procedure;[2] and he carefully tested Hillischer's apparatus. He found that by Hillischer's method it was impossible to finely adjust the oxygen supply; that the channels through the apparatus were too narrow to allow of free respiration; that the administrator required the services of an assistant in order to keep the gas-bags properly filled; and that the apparatus was not sufficiently portable to fit it for the requirements of English practice. He therefore devised an apparatus which was free from these objections; and as it has for many years fulfilled its requirements, the remainder of this section will be devoted to describing its action and the type of anæsthesia which it is capable of producing.

The Author's Method of Administration

A. APPARATUS

Two cylinders of liquefied nitrous oxide and one of compressed oxygen

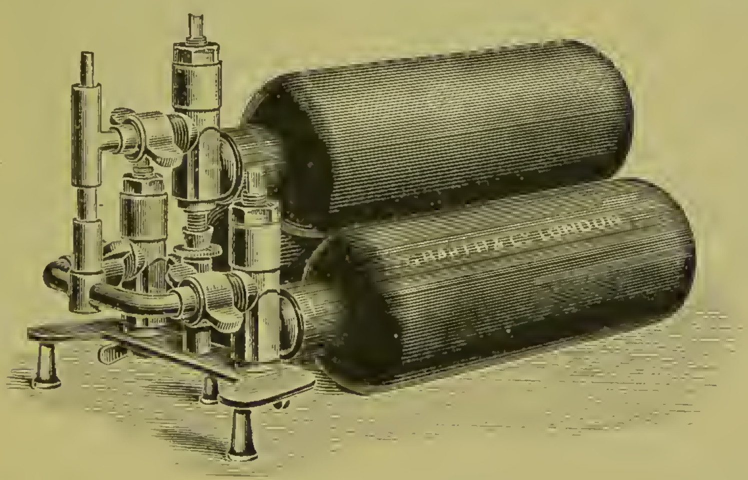


Fig. 29.—Stand and Union for the Nitrous Oxide and Oxygen Cylinders.

are needed. The stand for these cylinders is shown in Fig. 29. It is

[1] See a pamphlet by Dr. Hillischer, *Schlafgas*.

[2] In a paper which the author read at the Odontological Society (*Trans. Odont. Soc.*, June 1892) he described in detail the various methods which he tried.

constructed with the object of being as portable as possible, the oxygen cylinder being placed above two nitrous oxide cylinders. When the nitrous oxide is released by working the foot-key, it passes into the vertical brass tube of large calibre at the extreme left of the wood-cut. When the oxygen is released, it passes into the vertical brass tube of smaller calibre which is seen to be emerging from the centre of the nitrous oxide tube. To these two brass exit tubes, one inside the other, two corresponding rubber tubes are attached for the transmission of the respective gases to the double bag shown in Fig. 30. It will be seen that the first few inches of the nitrous oxide transmission tube are surrounded by spiral wire to prevent kinking. When the two tubes approach the double bag they are made to pass independently by means of a Y-piece

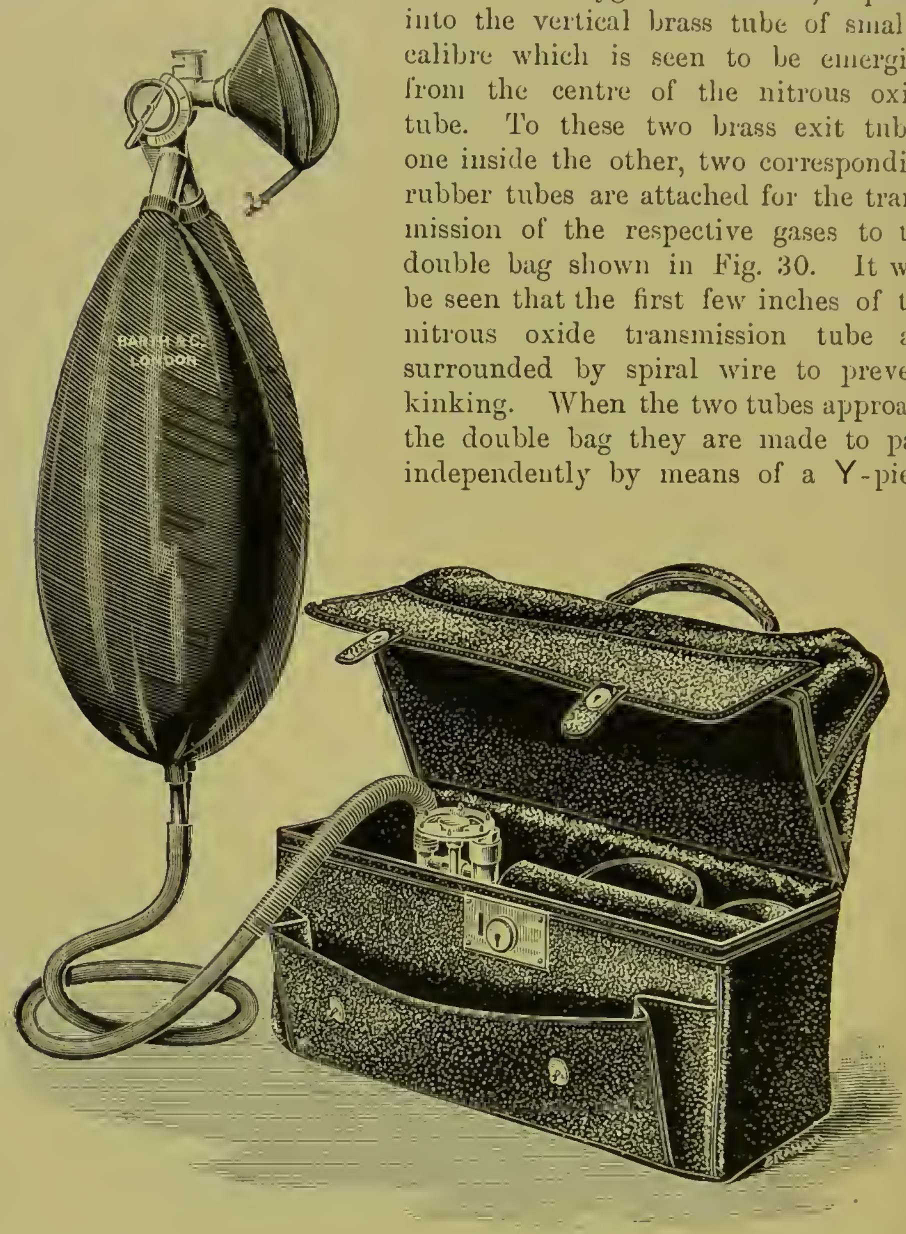


FIG. 30.—The author's Apparatus for administering Nitrous Oxide and Oxygen to patients in the sitting posture.

to supply this double bag with the two gases. To the double bag the regulating stopcock is attached. The latter is shown in detail in Fig. 31. NOT is the nitrous oxide tube, with its removable inspiratory valve *iv'*. This is the tube to which the nitrous oxide half of the double bag is attached. OT and *iv* are the oxygen tube with its inspiratory valve.

Nitrous oxide passes along NOT and through the large orifice NOO to the mixing-chamber in which revolves the inner drum ID with its large slot S. The handle has an indicator which may be turned to various points on the flange shown in the wood-cut. The oxygen which passes along OT enters the little oxygen chamber OC, from which it passes to the mixing-chamber through the 10 small orifices OO, any number of which may be opened by rotating the inner drum. All the 10 oxygen orifices are of the same size except the first, and by means of the supplementary stopcock SS, this can either be made of the same size as the other 9 (first position of SS), or it can be made equal to the 10 orifices collectively (second position of SS), or to 20 such orifices (third position of SS). From the mixing-chamber the gases are inhaled through the main inspiratory valve IV, expiration escaping at the expiratory valve EV. PD is a partial diaphragm which serves to direct the expirations upwards towards EV. When the inner drum is in position, and the indicator points to "AIR," air enters the stopcock at AH, and is breathed through IV and EV, the nitrous oxide and oxygen both being shut off. As the handle H is raised, the indicator passes from "AIR" to "N_2O," and pure nitrous oxide is breathed, because AH and OO are closed and NOO is open. If the handle H be still further raised, the indicator passes to "1," which means that whilst the nitrous oxide orifice NOO is still open, and the patient is breathing nitrous oxide, the first of the 10 oxygen orifices is also open, and oxygen gains admission with the nitrous oxide to the air-passages. At the commencement of the administration, SS is so adjusted that the first oxygen orifice is the size of the rest, so that when the indicator points to "1," only a small percentage of oxygen, 1 per cent or less, is breathed. By moving the indicator to "2," "3," etc., any number of the 10 oxygen orifices may be opened, and a corresponding number of small streams of oxygen added to the nitrous

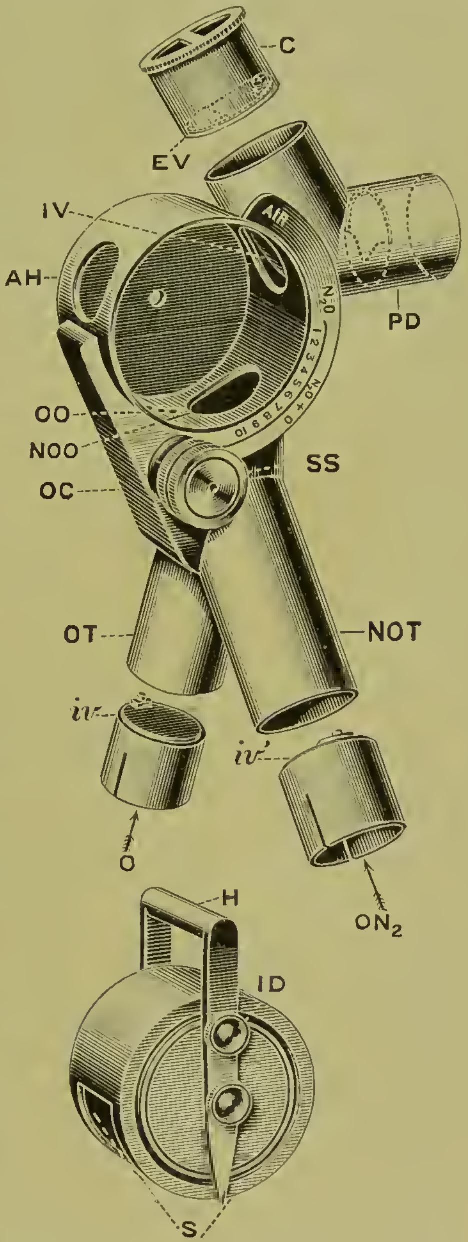


FIG. 31.—The Regulating Stopcock and Mixing-chamber shown in detail.

oxide. If more oxygen be required than can pass through with the indicator at "10," the supplementary stopcock SS may be turned to its second position (= ten extra holes) and the indicator brought back to "2," when an amount of oxygen corresponding to that which would pass through eleven holes will be inhaled. If the indicator be made to pass to "3," whilst SS is in its second position, twelve holes will be opened; and so on. If large quantities of oxygen be needed, SS may be turned to its third position (= twenty extra holes). By this arrangement the administrator has at his disposal, so to speak, 29 oxygen orifices. The precise percentages of oxygen coming through these orifices will depend upon numerous circumstances, and the numbers given do not represent percentages. It is not necessary that the precise percentages of oxygen should be known. Each apparatus will be found to have its own particular characters, and these characters will always repeat themselves

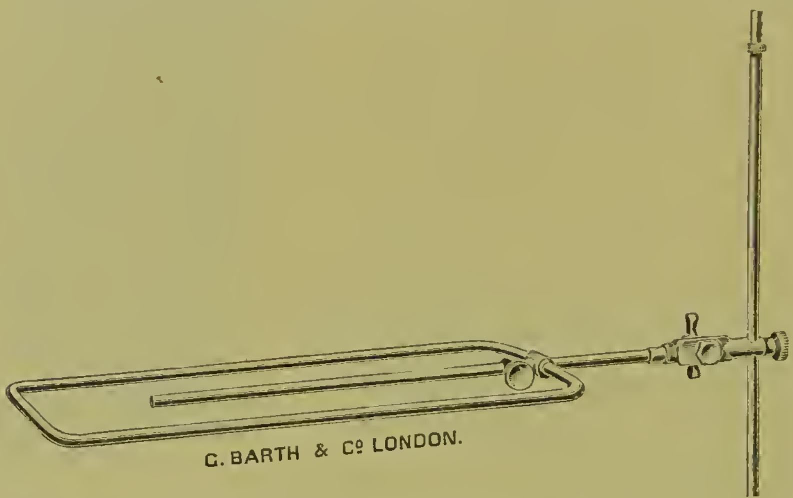


FIG. 32.—Portable Support for use in the Administration of Nitrous Oxide and Oxygen to horizontally placed Patients.

under the same circumstances. One apparatus may let through more oxygen than another; but the proportions can be easily graduated. It is very important that the rubber bags and all valves should be kept in good order. The valves require to be renewed occasionally.

If the operation is to be performed with the patient in the sitting posture, the apparatus shown in Fig. 30 (p. 308) will answer as well as any. If, however, the patient be lying in bed or the operation be of such a nature that the dorsal, dorso-lateral, or lateral posture is requisite, some difficulty may be experienced, with that particular apparatus, in keeping the gaseous contents of the joined bags at equal pressures. This is owing to the fact that when patients are thus placed it is frequently necessary to allow the bags to partly rest upon the edge of the bed or table. The author has accordingly slightly modified the apparatus of Fig. 30 to suit the requirements of general surgery, and the results have been very satisfactory. It may be mentioned that the modified apparatus is equally applicable in dental and other operations necessitating the sitting posture. Two separate bags are employed, instead of two joined bags. These are

supplied with their respective gases *from above*, so that there is no tubing below to exert traction upon the walls of the bags. By means of an adjustable metal support (Fig. 32) the stopcock, with its dependent bags, free from all extraneous pressure, may be rigidly fixed at any height at the side of the bed. Two lengths of wide-bore tubing are supplied with the apparatus, by the use of which tubing the face-piece is connected to the stopcock. The cylinders may be worked either by the foot or by the hand.

B. THE ADMINISTRATION

The type of subject must be taken into consideration. Just as with ether and with chloroform it is impossible to produce the best results on all occasions, so it is impossible in the case of nitrous oxide thus administered. The best subjects for this method are middle-aged women of placid temperament. Weakly middle-aged men are also good subjects, unless possessing so much hair about the face as to make it difficult to obtain a proper fitting of the face-piece. Muscular or heavily-built men, obese and elderly patients of both sexes, and all persons who smoke or drink to excess are comparatively difficult to anæsthetise by this method. Boys and girls, especially if florid, may secrete much mucus and saliva and display a tendency to retching and vomiting. Young women are favourable subjects as a general rule. Young men often give trouble by reason of muscular spasm. Patients with adenoid growths, enlarged tonsils, and allied conditions may also give trouble, and may require a larger percentage of oxygen than usual. Alcoholic subjects display a tendency towards "jactitation," and are very susceptible to the deprivation of oxygen, so that the best results are to be obtained by the prolonged administration of a mixture comparatively rich in this gas.

In order to obtain the best results, the patient must be as carefully prepared as for any other general anæsthetic; and special attention should be paid to the posture in which the administration is conducted. If the sitting posture be adopted the remarks made on p. 201 must be borne in mind. For general surgical work the dorso-lateral or lateral posture (Fig. 33) is the best; but the dorsal position may be permitted, provided the patient's head be turned well to one side.

The anæsthetist should make sure that he has a sufficient supply of the two gases, and that his apparatus is in perfect working order. The bags should not be charged until immediately before the administration, and they should then be half filled with their respective gases. In general surgical practice it is a good plan to place a small wooden mouth-prop (Fig. 16, p. 256) between the teeth, particularly if there be the slightest nasal obstruction. In dental practice one of the mouth-props shown in Fig. 19, p. 258, should be introduced. The face-piece should be carefully chosen; for want of co-aptation will lead to partial or complete failure. When the face-piece is applied, air will be breathed freely through the apparatus, and the sound of the acting valves will prove that the face-piece fits well. If there be much hair about the face a folded wet napkin should be placed around the cushion of the face-piece. The patient should be instructed to breathe freely and moderately deeply, "in and out through the mouth."

When the administrator sees and hears that breathing is free, the indicator may be turned to "2." Nitrous oxide with a small percentage of oxygen will thus gain admission to the lungs. It is best to commence with a comparatively small percentage of oxygen, as we have to allow for that originally present in the lungs and blood. If we begin with, say, 10 per cent, excitement will be liable to arise. After two or three seconds the oxygen indicator may be turned to "3," and in a few seconds more to "4." In the case of children, anæmic subjects, and debilitated persons, the indicator may be moved to "3" and "4" more quickly than in the case of strongly-built individuals. During these manipulations the two bags must be kept as nearly as possible equal in size. It is rarely, if ever, necessary to replenish the oxygen bag during the administration for a dental operation, but the foot or hand must be constantly kept working the nitrous oxide key. In general surgery, when a more or less protracted administration is called for, fresh oxygen must be admitted to the bag from time to time. Considerable practice is necessary to keep both bags equal in size and partially distended throughout. Should phonation, laughter, excited movement, or struggling assert

itself, the administrator must turn back the indicator for a few breaths. In 40 or 50 seconds from the commencement of the inhalation the indicator may usually be allowed to point to "5," and in 20 seconds more to "6," "7," or even "8." Generally speaking, it is not advisable, in a dental administration, to give more oxygen than this. In general surgical cases, however, a progressive increase in oxygen is necessary—that is to say, the longer the patient has been inhaling the mixture, the greater should be the proportion of oxygen. General surgical procedures may usually be commenced about two minutes after the face-piece has been applied. From this point onwards the anæsthetist will find that he has to pilot his patient along a narrow channel. On the one side he will have to avoid the clonic respiratory movements, etc., which prevent a free and lengthy intake of the anæsthetic; and on the other any inconvenient signs of incomplete anæsthesia. He must be sparing in his addition of oxygen when anæsthetising those patients whose appearance suggests that they will be likely to require what we may call, for want of a better term, a strong dose of the anæsthetic. Patients who are easily affected by anæsthetics—such, for example, as children and debilitated persons of both sexes—may invariably be anæsthetised by nitrous oxide with considerable percentages of oxygen. The author finds, for example, in anæsthetising such patients, that after 5 or 10 minutes' inhalation he can usually keep open about 20 of the minute oxygen orifices in the apparatus. A similar tolerance of large proportions of oxygen will be met with in asthmatics and other patients who may be suffering from respiratory difficulties. In protracted administrations it may be advisable to admit an occasional breath of fresh air. Should inconvenient stertor arise, oxygen must be more freely admitted, and the jaw pressed forwards (p. 529) as in administering other anæsthetics. The longest administration the author has conducted without allowing even one breath of air was one which lasted 35 minutes.

If a protracted administration be required and the bedstead upon which the patient is lying be of inconvenient proportions, it is a good plan to reverse the patient's position,

placing his head at the foot of the bed, as shown in Fig. 33. It is in such cases as these that the second of the two forms of apparatus above described is very convenient. The support shown in Fig. 32 should be inserted between the bed and the

FIG. 33.—The continuous Administration of Nitrous Oxide and Oxygen for a General Surgical Operation.

mattress. The stopcock is then fitted to the support; the bags attached to the stopcock; and the face-piece is connected to the stopcock by means of one or both inhaling tubes, according to the distance of the patient from the side of the bed. By using this modified apparatus for general surgical cases, a smoother form of anæsthesia is secured than with the

apparatus of Fig. 30, which is more particularly adapted for dental administrations.

C. EFFECTS PRODUCED

First Degree or Stage.—This is very similar to that already described as occurring under nitrous oxide. There is, however, one noteworthy difference, viz. that the presence of even a small percentage of oxygen more or less completely removes the *besoin de respirer* so common with pure nitrous oxide.

Second Degree or Stage.—Consciousness is lost a trifle later than with pure nitrous oxide; and the period that elapses between loss of consciousness and the establishment of anæsthesia is longer. Neurotic and alcoholic subjects, as well as those whose nervous systems have become undermined by excessive work, worry, etc., may move their arms or legs, laugh, or gesticulate during this stage. Excitement occurring during the administration may usually be at once stopped by diminishing the percentage of oxygen. The respiration during this stage not unfrequently becomes very deep and rapid, and then abruptly calm or even imperceptible. There is no cause for anxiety in this rapid respiration; it always coexists with a good regular pulse and florid colour, and gradually gives place to tranquil, unembarrassed, and distantly-snoring breathing, as deep anæsthesia approaches.

Third Degree or Stage.—When the typical anæsthesia of nitrous oxide and oxygen has become established, the patient's condition will be suggestive of natural sleep.

The **respiration** is usually remarkably calm and perfectly regular during this stage. A barely audible inspiratory roughness or snoring is not uncommon. The loud "stertor" of an ordinary nitrous oxide administration is never met with. Respiration is rhythmically performed. Owing to there being less venous engorgement, and hence less swelling of all parts within the upper air-tract, than when nitrous oxide is given in the ordinary manner, patients with enlarged tonsils may be anæsthetised with comparatively little tendency to obstructed breathing.

The **colour of the face and lips** varies. In some cases the

patient becomes a trifle paler than usual; whilst in others, and especially in those previously pale from apprehension, the colour becomes more florid. The duskiness and lividity so common under pure nitrous oxide are, generally speaking, entirely absent. As will subsequently be pointed out, it is sometimes necessary during the administration of the mixture, either to bring down the proportion of oxygen below 10 per cent, or to give pure nitrous oxide for a short period; and under such circumstances a variable degree of duskiness would of course ensue.

The **circulation** is well maintained during deep anæsthesia. The pulse is invariably accelerated; but it is neither as quick nor as small as the pulse under pure nitrous oxide.[1] The author has administered nitrous oxide with oxygen to patients whose circulatory functions were at the time of inhalation seriously disorganised, and can testify to the very satisfactory manner in which the mixed gases have been taken. He has given the mixture to a patient in a half-fainting condition, sitting vertically in a chair, and has found an almost imperceptible pulse to become perceptible and of fair volume during the inhalation. Dr. Leonard Hill, working with his "sphygmometer," finds that the arterial pressure either rises slightly or remains constant.

Clonic **muscular movements** are usually conspicuous by their absence; and the so-called "jactitation" of nitrous oxide is, with the rarest exception, never witnessed. A minor degree of tonic spasm in the muscles of the neck, back, and extremities is often manifested, more especially as the immediate reflex result of the operation. Opisthotonos very rarely occurs.

The condition of the **eyelids, globes, and pupils** deserves special notice. The eyes usually remain closed throughout the administration. During the first 45 or 60 seconds any attempt to raise the upper lid will cause a reflex tightening of the orbicularis. This spasm, however, gradually passes away as the inhalation proceeds, and at the end of about 75 or 90

[1] Dr. Walter Broadbent (*Brit. Med. Journ.*, 8th July 1899) publishes an interesting pulse-tracing under nitrous oxide and oxygen, showing some lowering of tension, which he believes is due to peripheral dilatation.

seconds the upper lid may usually be raised without resistance. The eyeballs will now be found to be fixed, and in many cases turned to the right or left. In some instances there may be observed slight oscillatory movements of the globes; not as rapid as those of ordinary nystagmus, but not so slow as those which would indicate conscious observation. The pupils are variable. As a general rule they are of moderate size. Wide dilatation is distinctly rare. The author has on many occasions witnessed contraction and dilatation of the pupil in almost immediate response to a greater or less percentage of oxygen. The pupils may of course reflexly dilate during the extraction of a tooth, even though the patient be absolutely unconscious and free from all pain. The conjunctival reflex is, in the vast majority of cases, quite absent, though the cornea is generally sensitive to touch. After a protracted administration, however, the cornea may lose its sensibility.

Reflex **phonation**, as for example during tooth extraction, is uncommon. Of 153 dental cases the author noted it, more or less, in 29.

Anæsthesia is known to be present by one or all of the following signs:—

1. The conjunctival reflex is lost;

2. The breathing is regular and tranquil, or is softly snoring in character (like the breathing of good chloroform anæsthesia);

3. The arms are flaccid; and

4. The eyeballs are fixed or present slight oscillatory movements.

In some cases the muscular system, instead of being relaxed, is rigid at the acme of anæsthesia, but such cases are exceptional. Alcoholic patients appear to be particularly liable to this rigidity.

The **period of inhalation** requisite to secure deep anæsthesia varies considerably in different cases; some patients being, for reasons already given, far more quickly and deeply affected by nitrous oxide than others. Of sixty-seven carefully (métronome) timed dental administrations with the apparatus above described, the author found the average period of inhalation to be **110·5 seconds**, a figure which represents the average period of inhalation found necessary to provide the operator with a subsequent

anæsthesia of sufficient duration for the performance of an average dental operation.

In sixty-nine carefully (métronome) timed dental administrations, the average **period of available anæsthesia** was **44 seconds.** It is right, however, to point out that great variation occurs in the duration of this period. The longest anæsthesia was 90 seconds, the shortest 21 seconds. Within certain limits, the longer the administration the longer will be the subsequent anæsthesia. The following figures are of interest in this connection :—

Anæsthetic employed.	Average Period of Inhalation for Dental Operations.	Average Period of Resulting Anæsthesia.
Pure nitrous oxide . .	about 56 secs.	about 30 secs.
Nitrous oxide mixed with a percentage of oxygen sufficient to prevent asphyxial phenomena	about 110 secs.	about 44 secs.

So far as the simple maintenance of unconsciousness is concerned, this system may be regarded as applicable in general surgery; but as the surgeon of the present day very properly requires that his patient shall not only be unconscious but tranquil and immobile, it can hardly be contended that the anæsthesia from nitrous oxide and oxygen will always meet his requirements. As already pointed out, the anæsthesia is comparatively light; and inconvenient reflex movements may hence arise. It is true that the tendency to these reflex phenomena gradually lessens as the administration proceeds; but this fact does not wholly dispose of the objection. Skin incisions, particularly about the lower extremities, and procedures within and about the rectum or genito-urinary organs, are especially liable to lead to inconvenient reflexes. Alcoholic subjects, those who smoke to excess, highly neurotic persons, and vigorous young men and women are especially likely to evince such phenomena. Even with the best subjects the repeated administration of these gases has a tendency to induce a comparative insusceptibility to their influence, so that it may become increasingly difficult to secure the desired

degree of relaxation and freedom from movement. In addition to these objections to the system, it must be remembered that the administration of the two gases for a lengthy operation is by no means an easy matter; for not only is it difficult to be certain of having a sufficient supply of the two agents, but it is somewhat irksome to carry out the numerous manipulations for a protracted period. Moreover, although it was at one time thought that this system of anæsthetisation would prove to be invariably free from after-effects, this is unfortunately not the case. Other things being equal, there is certainly less risk of nausea and vomiting than after ether or chloroform; but the author has notes of several cases in which gastric after-effects assumed distressing proportions. In one case in which he administered the gases for the removal of the breast, the vascularity of the parts was as great as it usually is under ether; and the patient, who was particularly anxious to avoid this latter anæsthetic, because of previous experiences, was sick for many hours after the administration. It is true that such cases are very exceptional, but they must not be ignored.

The author has administered nitrous oxide and oxygen for Syme's amputation, lithotrity, removal of the breast, excision of varicose veins, varicocele, removal of ossicles of internal ear, resection of the patella, removal of necrosed bone from a tubercular hip, several intra-uterine operations, the removal of epitheliomatous glands from the groin, and for a large number of minor surgical operations. In one minor surgical case (dressing wound and readjusting splints) the administration lasted 52 minutes,[1] in which time 200 gallons of nitrous oxide and about 25 gallons of oxygen were used. As already indicated, good and tranquil anæsthesia can only be secured *in certain types of subjects*; and even when dealing with such types there are only certain operations that should be undertaken. For example, to attempt to anæsthetise by this system a vigorous, thick-set, alcoholic man for a rectal operation would be but to court failure. On the other hand, to employ this form of anæsthesia for some comparatively trifling operation upon a middle-aged and non-excitable lady

[1] A case is recorded in which the administration lasted 135 minutes. *Lancet*, March 1902. Soc. of Anæsthetists.

who had on a previous occasion been greatly distressed by the taste and after-effects of ether or chloroform would be the best line of practice. A careful selection of cases is, in fact, essential, and if such a precaution be adopted, the anæsthesia of nitrous oxide and oxygen will be found to be of the greatest possible value. When a patient who is a good type of subject for an anæsthetic (p. 152) requires an operation of from 5 to 10 minutes' duration; when slight reflex movement, should it occur, would not embarrass the operator; when other anæsthetics have produced very unpleasant after-effects; and when the patient can be so placed (Fig. 33) that the administration can be properly conducted, the results will, as a rule, be most gratifying. It is a matter of no small importance to a highly nervous and fastidious patient to know that he can be anæsthetised with perfect safety; to pass into anæsthesia without discomfort or suffocative sensation in about seven or eight breaths; to be kept in a state of complete oblivion during some surgical operation; to regain consciousness without nausea or unpleasant taste; and to be able to take nourishment of some sort after a short interval.

D. DANGERS CONNECTED WITH THE ADMINISTRATION

There is no form of anæsthesia at present known which is so devoid of danger as that which results from nitrous oxide when administered with a sufficient percentage of oxygen to prevent all asphyxial complications. The author has employed this system up to the present time (October 1906) in about 17,000 cases, as near as he is able to estimate, and with the exception of two or three cases, in which, owing to the percentage of oxygen having been insufficient, transient respiratory embarrassment arose, and of one case in which transient syncope, probably of reflex origin, took place (*vide infra*), he has had no cause for anxiety. Owing to the fact that little or no strain is thrown upon the circulation, persons with feeble and dilated hearts are anæsthetised by nitrous oxide and oxygen without that slight risk which obtains when the former gas is administered alone. Moreover, those patients who, by reason of senile or other changes in the thoracic

parietes, pleuræ, or lungs, might evince symptoms of embarrassed breathing at the acme of ordinary nitrous oxide anæsthesia, are certainly less likely to do so in the presence of oxygen. So far as the author is aware, no fatality has yet been recorded under nitrous oxide and oxygen.

E. RECOVERY: AFTER-EFFECTS

The recovery from the effects of this mixture, when administered for a dental or other minor operation, is usually very satisfactory, though not quite so speedy as from nitrous oxide alone. We cannot be surprised at this difference, seeing that the inhalation is invariably longer when nitrous oxide is given with oxygen. The difference, however, is slight; and when the inhalation has been short, there is practically none to be detected. It is only when an inhalation of two to three minutes, or longer, has been conducted, that the more tardy recovery manifests itself. The longer the inhalation, the greater will be the tendency to after-effects. **Nausea** or actual **vomiting**, although rare, is more common than after nitrous oxide alone—a fact which must not be lost sight of.

In a few instances the author has met with slight **pallor, feebleness of pulse, and faintness**; but he has never seen such symptoms assume grave proportions.

In one case in which temporary syncope occurred, the patient was in the habit of fainting in hot rooms and in church. She was twenty years of age and 6 feet in height. She was placed deeply under nitrous oxide and oxygen for the extraction of a tooth. There was no reflex movement during the operation. After the tooth had been removed she remained unconscious for about a minute with considerable pallor and feebleness of pulse. The author bent her forwards in the chair with her head low. Recovery was gradual, with a feeling of "pins and needles."

It is quite possible, and indeed probable, that this condition was of reflex origin, in other words, that the state was one of slight circulatory shock (p. 253). The case is interesting when read in association with the cases of surgical shock in Chap. XIX., in several of which there was a similar history of previous syncopal attacks.

The author has notes of three cases of **transient maniacal excitement** immediately after the administration. In all three cases the patients were men of powerful build.

Mr. Edgar Willett[1] has recorded a case in which, after a few minutes' inhalation of nitrous oxide and oxygen, the patient remained practically asleep for four days.

After the more protracted administrations of general surgery, gastric after-effects are not uncommon. This point has been referred to above. As with other anæsthetics, much will depend upon the duration of the administration and the type of subject.

F. ILLUSTRATIVE CASES

In the following table are given four illustrative dental cases. The times were taken by a métronome, and an assistant recorded the symptoms of the patients. The table shows the effects of more and less oxygen, the intervals at which this gas was admitted, and many other points.

[1] *Lancet*, March 1902. Soc. of Anæsthetists.

[Table.

Illustrative Case, No. 2.

A typical case.

Sex and Age.—M. 18.

Description.—Fairly nourished; good colour. A postman.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
18	3	Six breaths taken.
33	4	
39	4	Deep respiration.
51	5	
72	5	Quieter breathing.
78	6	
90	6	No conjunctival reflex.
99	6	Pupils $3\frac{1}{2}$ mm. in diameter.
108	6	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Good colour.
9	No movement or phonation.
21	Opposite side of mouth being operated upon.
30	Operation over.
42	Anæsthesia at an end.

Teeth or stumps extracted.—4.
General result.—Typical.
Remarks.—No pain. No phonation or movement; no stertor or muscular twitching; good recovery; dreamt he was at his work.

Illustrative Case, No. 3.

A typical case except for slight duskiness. See remarks.

Sex and Age.—F. 33.

Description.—Spare; sallow.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
12	3	
24	4	
39	5	
51	6	
57	6	Twitching of eyelids.
66	6	Conjunctival reflex not abolished.
72	7	
78	7	Restless movement in chair.
81	5	
84	3	
87	2	
93	3	Movement ceased.
96	5	
108	5	Slight conjunctival reflex.
120	5	No conjunctival reflex.
123	5	Breathing quicker and more audible.
126	5	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Distinctly dusky.
9	Very slight phonation.
12	Normal colour returned.
24	Some movement of legs.
30	Anæsthesia at an end.

Teeth or stumps extracted.—4.
General result.—Good but not typical.
Remarks.—Restless movements probably due to too much oxygen at 72 secs. Movements quite controlled by less oxygen (more N_2O); but some duskiness at end due to this diminished quantity. Otherwise typical. No "stertor" or "jactitation."

Illustrative Case, No. 4.

Long inhalation and long anæsthesia after.

Sex and Age.—F. 33.

Description.—Fairly well nourished; fair complexion.

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	2	
18	3	
30	4	
36	5	Quicker breathing.
54	6	
60	6	Quieter breathing.
72	6	Soft snoring.
84	6	Ditto.
96	7	Distinct conjunctival reflex.
108	7	Snoring passing off. Slight rigidity of neck.
132	7	Tendency to turn head to left. Conjunctival reflex still present.
150	8	Very slight snoring.
171	8	Conjunctival reflex slight.
177	8	Some phonation.
180	8	Breathing quicker and more audible.
186	8	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
9	Some phonation.
18	Phonation ceased, operation proceeding.
27	Slight rigidity, good colour.
48	Movement of hand towards head.
66	Extraction finished.

Teeth or stumps extracted.—4.
General result.—Very good, barely typical.
Remarks.—She slightly felt the last stump. Probably deduct 6 secs. from 66 above mentioned. Instance of long administration and long anæsthesia. A good deal of oxygen given.

Illustrative Case, No. 5.

Too much oxygen given intentionally for purposes of demonstration. Excitement thus produced easily controlled.

Sex and Age.—F. 37.

Description.—Healthy appearance. (Pulse 120 before prop inserted.)

A.—*Period of Inhalation.*

Secs.	Oxygen Indicator at	*Symptoms.*
0	3	
6	3	Pulse 132.
18	4	
21	4	Pulse 144.
33	4	Average breathing.
36	4	Tranquil breathing.
42	5	
51	5	Very calm breathing.
54	6	
66	5	Slight evidences of approaching excitement.
69	4	
72	4	Some phonation.
78	3	Restless movement in chair, with tendency to slip forward.
81	3	Pulse 120.
84	4	
93	5	Quite quiet.
102	5	Inhalation stopped.

B.—*Available Anæsthesia after Removal of Face-piece.*

Secs.	*Symptoms.*
3	Colour a trifle dusky.
15	No phonation.
21	Conjunctiva insensitive.
36	Anæsthesia at an end.

Teeth or stumps extracted.—1.
General result.—Very good, barely typical.
Remarks.—Started with oxygen indicator at "3" instead of "2," and turned it to "4" in 18 seconds.

CHAPTER X

THE ADMINISTRATION OF ETHER

The reader is referred to Chap. I. pp. 5 and 7 for a short account of the discovery and early use of this anæsthetic; to Chap. II. p. 21 for information upon its chemical and physical properties; to Chap. IV. p. 101 for a *résumé* of the chief experimental work that has been done concerning its physiological action; and to Chaps. V., VI., and VII. for remarks as to its safety and suitability in general surgical practice.

A. APPARATUS AND METHODS OF ADMINISTRATION

Ether may be administered—

I. By the **open** system—a plentiful supply of atmospheric air gaining access to the lungs throughout the administration;

II. By the **semi-open** system—the inhaler employed limiting to some extent the access of atmospheric air without in any way retaining the expiratory products for re-breathing;

III. By the **close** system—the air-supply being intentionally restricted, and the expiratory products retained for re-breathing;

IV. **In conjunction with oxygen** instead of atmospheric air; or

V. By the introduction of the vapour into the rectum **(rectal anæsthetisation).**

I. *The Open System of Etherisation*

As a general rule it is impossible to produce deep anæsthesia by this system, although it may be used in infants, in extremely exhausted subjects, or in patients who have been for some time deeply anæsthetised, and who, in consequence,

require minimal doses of ether to maintain insensibility. Ether is added, in small quantities at a time, to a folded cloth or handkerchief, or a Skinner's mask.

The following case illustrates the method in question.

Illustrative Case, No. 6.—Infant seven weeks old. A rather weakly but not anæmic child. Was at the breast three hours before. Circumcision. Commenced at 9.45. A.M. with Robbins's ether. Administration 15 minutes. Ether dropped on Skinner's mask. Some crying, lasting 2 or 3 minutes. Mask now fairly wet with ether. No cough or prolonged holding of breath. By degrees respiration more regular and of higher pitch, then quite regular. Arms a trifle rigid. Very slight movement of legs. Operation begun. Trifling reflex movement, and crowing breathing. Respiration, as a rule, regular and easy; inspiration and expiration attended by similar sounds. No mucus. Pupils 3 mm. Flaccid. No conjunctival reflex. Pulse full and quick. Face very red. About $\frac{1}{2}$ a drachm of ether now added at a time. The following were the indications of "coming round":—Commencing rigidity of arms; hesitating breathing; movement of legs; and then phonation. Quick recovery. No vomiting.

II. *The Semi-open System of Etherisation*

When ether was first introduced, it was administered by means of a towel folded and pinned into the shape of a cone, and at the apex of this cone a sponge was placed for the reception of the ether. The sponge was usually wrung out in warm water before use. The anæsthetic was poured upon the sponge in small quantities at a time, and the cone applied, more or less continuously, to the face of the patient. Cone-shaped inhalers of felt, with an outer covering of mackintosh to prevent undue evaporation, were then devised, and are still used by some. These cones are also furnished with sponges, and are slightly open at their apices, so that air may gain admission. They have been used for a great many years both in England and in America, and certainly have the merit of simplicity. One of the best of the open ether inhalers is shown in Fig. 34. It is known as Rendle's mask. The inhaler is made of leather, celluloid, or metal, and has numerous holes at its rounded end. A long, large-mouthed bag of domett or flannel is used as a lining, its mouth being brought back over the mouth of the inhaler, so that when the latter is applied to the patient's face, a soft surface of domett or flannel comes against the cheeks. A sponge

FIG. 34.—Rendle's Inhaler.

is placed at the bottom of the inhaler, and ether is poured upon it. Inhalers of celluloid or metal are preferable to those of leather, as they are more readily cleansed. In some modifications of Rendle's inhaler the free rim is fitted with an inflatable rubber cushion. Others possess ingenious devices for preventing any excess of ether that may be present from reaching the patient's face. A Rendle's inhaler of small size is the best of all known ether inhalers for small children (pp. 328 and 490). In the rare instances in which a semi-open inhaler is indicated for an adult subject, this variety of inhaler is also applicable, although a Clover's inhaler without its bag will answer quite well. In America, Allis's inhaler, an apparatus of the semi-open type, is largely used. Numerous other semi-open ether inhalers have been devised, but want of space prevents any reference to them here.

The **administration of ether by means of a semi-open inhaler** is such a simple procedure that details are hardly necessary. In adults a drachm or two should be first placed within the inhaler, and the latter held that distance from the face which is found to be necessary in order to avoid cough or holding the breath. Too strong a vapour will cause instant closure of the larynx and a sense of suffocation. The administrator must steer between too sparing and too liberal a use of the anæsthetic. If very small quantities be given, the patient may never pass beyond the stage of ether intoxication. On the other hand, if too pungent a vapour be given, the patient will experience the most horrible sense of suffocation, the breath will be held for prolonged periods, and violent struggling will probably arise. It is therefore best to start with a vapour well diluted with air, according to the indications present, and when the patient is getting dazed and losing consciousness to gradually but progressively increase the strength of vapour. The effect of the ether upon the larynx must be watched, and the quantity regulated accordingly. Respiratory rhythm is always interfered with, more or less, by swallowing movements, temporary closure of the larynx, etc. By degrees, however, the larynx grows accustomed to the vapour; it becomes less sensitive, and respiration more regular. When once unconsciousness has become established, any tendency to excitement or struggling must be met by a more continuous application of the anæsthetic. There is practically no danger in pushing ether at this stage. Should the sponge of a semi-open inhaler become frozen by the evaporation of the ether, it

must be removed and immersed in warm water before being again used, otherwise it may be impossible to obtain a sufficient quantity of the anæsthetic from the inhaler. When administering ether by the semi-open system, large quantities may be needed to secure and maintain anæsthesia, especially in alcoholic and vigorous subjects. It would, for example, be necessary to have at hand at least two pints of ether in order to successfully anæsthetise an alcoholic and stalwart patient for an operation of considerable duration. A very large proportion of the agent is wasted; and the room may become almost unbearable from the presence of so much vapour. Excitement and struggling are far more common than when a close inhaler is employed. The risk of catarrhal, bronchial, and pulmonary affections is probably greater in administering ether by the semi-open than by the close system.

Although semi-open etherisation has many objections as a routine procedure, it has advantages in certain cases. There is nothing simpler than to pour ether from time to time into a cone; and when a totally inexperienced practitioner is called upon to anæsthetise a patient he will be less likely to do harm by administering ether as above described than if he employs a close inhaler. In very exhausted and cachectic patients, in those suffering from advanced morbus cordis with orthopnœa, and in some of the worst cases of empyema, semi-open etherisation will be found to be of advantage. There is no objection to preceding ether by a small quantity of the C.E. or A.C.E. mixture (see Illustrative Case, No. 24, p. 489). In certain desperate cases of intra-pulmonary or pleural disease oxygen may be administered with the anæsthetic (see p. 340).

For short operations upon infants and small children there is no better line of procedure than that under consideration. A Rendle's mask of small size is the best form of apparatus, and ether is added to it in small quantities from time to time by means of a drop-bottle (Fig. 56). Almost constant lip-friction will be necessary in order to ensure regular respiration. The best guides as to the depth of anæsthesia are (1) the muscular tone of the arms and hands, and (2) the presence or absence, as the case may be, of breath-holding when the inhaler is reapplied. The operation may be begun when the

arms are relaxed and the rhythm of breathing is not affected by the application of more ether. For such operations as circumcision the method gives excellent results.

III. *The Close System of Etherisation* (*by means of Bag-Inhalers*)

It is doubtful who first recognised the advantages of limiting the access of fresh air during the inhalation of ether vapour. The late Professor J. Morgan of Dublin appears to have been the first writer in Great Britain who drew attention to these advantages,[1] but he refers to Professor Porta of Pavia[2] and to Dr. Smith of New York, both of whom had, prior to his (Dr. Morgan's) lectures, administered ether from a bladder or bag. Dr. Morgan's ether inhaler (described by him in 1872) consisted of a box or reservoir for the ether, and a flexible tube and mouth-piece through which the patient breathed the vapour. The box was furnished with an india-rubber diaphragm capable of expanding and contracting as the patient breathed.[3] In July 1876, Clover described[4] "An apparatus for administering nitrous oxide gas and ether singly or combined"; and at the time he wrote he had used this apparatus successfully in 2300 cases. The ether vapour, supplied from a reservoir, was breathed backwards and forwards from a bag attached to the face-piece, fresh air being admitted from time to time. In January 1877, Clover described[5] his "Portable Regulating Ether Inhaler" (Fig. 35). In February of the same year Dr. Ormsby of Dublin introduced[6] his apparatus (Fig. 42, p. 337) to the notice of the profession. Whilst Clover's ether inhaler has certain advantages over Ormsby's, the latter apparatus very favourably

[1] See an interesting article by Professor J. Morgan, entitled, "Ether *versus* Chloroform. On the uses of ether as an anæsthetic in surgical operations, as a safer and more efficient agent than chloroform in producing the avoidance of pain. With a description of an inhaler, and the mode of administration" (*Med. Press and Circular*, 31st July 1872).

[2] Asshurst, *Principles and Practice of Surgery*, p. 77.

[3] *Med. Press and Circular*, 28th August 1872, p. 165.

[4] *Brit. Med. Journ.*, 15th July 1876, p. 74. This apparatus will be referred to when discussing the administration of nitrous oxide with ether in Chapter XV. of this Part.

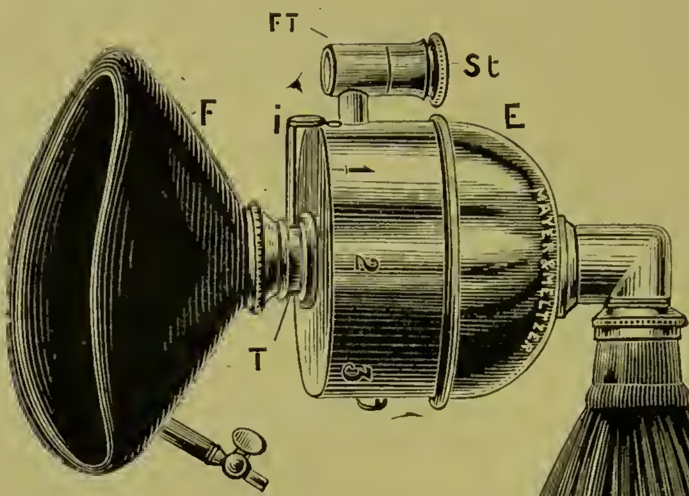
[5] *Brit. Med. Journ.*, 20th January 1877, p. 69.

[6] *Lancet*, 10th February 1877, p. 218; also 9th June 1877, p. 86.

compares with the former in many respects. The author will therefore fully describe these two inhalers, the method of using each, and the advantages of the one over the other.

Clover's Portable Regulating Ether Inhaler

This most ingenious and useful apparatus is represented in Fig. 35.



When ready for use it has the appearance represented. F is the face-piece ; E is the ether reservoir through which the air-current passes ; and B is an india-rubber bag. When the face-piece fits the face accurately, the patient breathes backwards and forwards into the bag. Mr. Pridgin Teale has very properly drawn attention to the importance of the face-piece in ether administration ; and in an excellent article[1] gives diagrams of good and bad face-pieces. Clover's apparatus possesses no valves, nor does it contain any contrivance for the admission of fresh air. The face-piece tightly plugs on to a tube (T), which fits into one end of a shaft passing through the ether reservoir. The mount of the bag B fits into the other end of this shaft. By revolving the ether reservoir on the tube T the current is made to pass to any desired extent over ether.

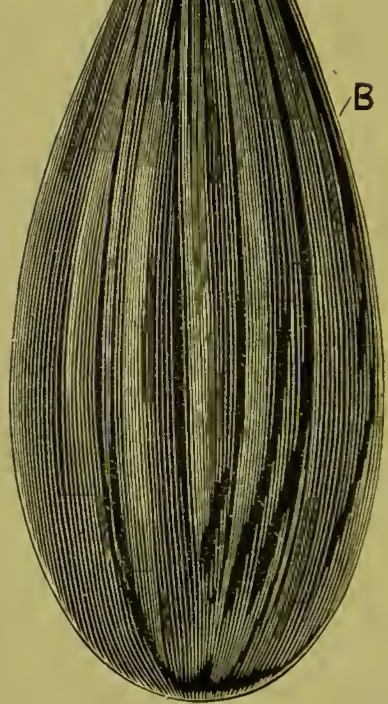


Fig. 35.—Clover's Portable Regulating Ether Inhaler. (Original pattern.)

[1] *Encyclopædia Medica*, vol. i.

The apparatus is charged with ether at the funnel-shaped tube FT, the stopper of which is removed for the purpose. The best kind of ether-

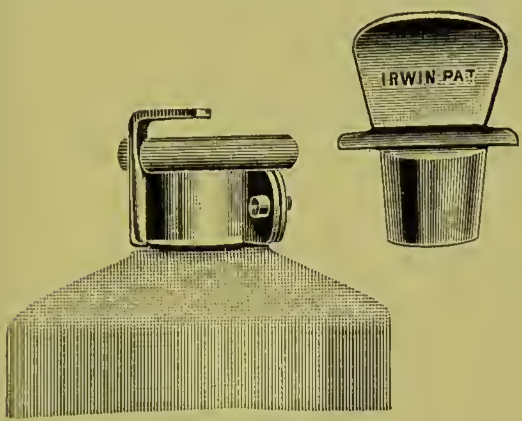


Fig. 36.—Irwin's Stopper.

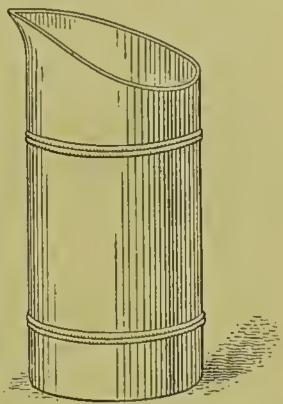


Fig. 37.—Measure for filling Clover's Ether Inhaler. (Half size.)

bottle is one fitted with what is known as Irwin's stopper,[1] shown in Fig. 36. The author has used this simple and excellent form of stopper

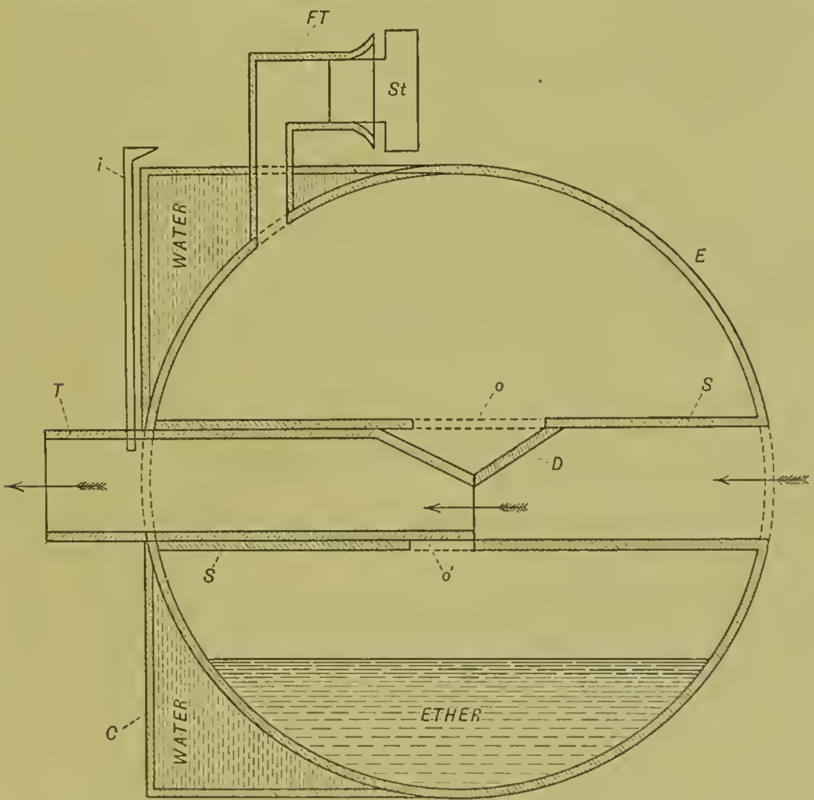


Fig. 38.—Section of Clover's Portable Regulating Ether Inhaler. (Original pattern.) Indicator at "0." (Two-thirds actual size.)

for several years, and finds it answers admirably. A little measure (Fig. 37), capable of holding about $1\frac{1}{2}$ oz. of ether, is usually supplied with the

[1] *Lancet*, 24th Sept. 1898.

inhaler, and is used for filling it with ether. The face-piece and bag hardly need further description; but the ether reservoir must be carefully considered, in order that the working of the inhaler may be understood.

In Figs. 38 and 39 the ether reservoir E and the tube T are shown in section. E consists essentially of a metal sphere tunnelled by the shaft S, into which T fits. The sphere is the reservoir for the ether. The filling tube (FT), closed with a stopper (St), is provided for charging the sphere with ether. Only one-half of the sphere is apparent in the finished apparatus, the other being covered in by a cylindrical cap or

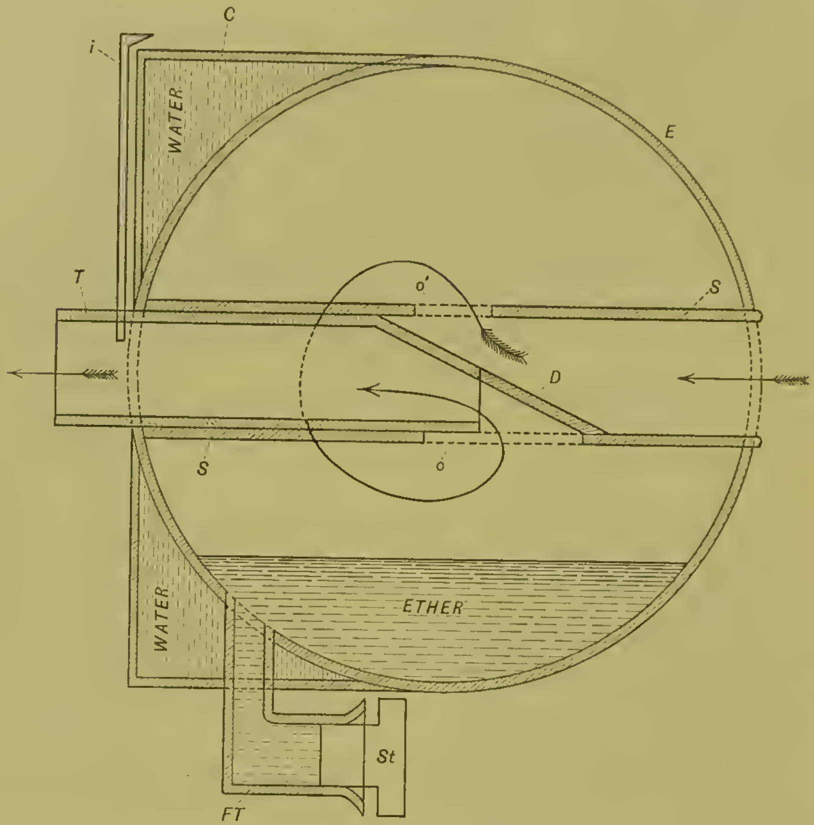


FIG. 39.—Section of Clover's Portable Regulating Ether Inhaler. (Original pattern.) Indicator at "F." (Two-thirds actual size.)

cover (C). The space which results is nearly filled with water by the makers of the instrument. This water-chamber prevents the apparatus from becoming too cold. When the temperature of the room is low, it is a good plan to immerse the inhaler in warm water for a few moments before use, by which plan the water in the water-chamber takes up and retains heat for a sufficient time to ensure a proper evaporation of ether in the adjacent sphere. About half-way along the shaft there are four large openings, two (O) on the upper wall of the shaft, and two (O′) on the lower. These allow of communication between the interior of the shaft on the one hand and the ether reservoir on the other. These openings are so large that the shaft S almost loses its continuity where they occur. Projecting from the wall of the shaft there is a half

diaphragm D, which closes up one-half of the calibre of the shaft, leaving the other half free. This half diaphragm is not fixed at right angles to the long axis of the shaft, but is sloped as shown. The tube T, upon which the face-piece plugs, passes into the shaft S. It has a whistle-shaped end which fits up against the half diaphragm D. It also carries a long rod or indicator (*i*), which points to figures on the circumference of the ether reservoir (Fig. 35). When the tube T is tightly plugged into the face-piece, as is the case when the apparatus is being used, the ether reservoir will rotate easily upon T, and the figures on the circumference will travel one after the other past the indicator (*i*). If the indicator point to "0," an inspiration will take the course shown in Fig. 38. It will pass straight through the shaft without entering the reservoir containing the ether. The openings (O and O′) in the shaft are unavailable, the upper ones (O) by reason of the half diaphragm D, and the lower ones (O′) by reason of the whistle-shaped end of the tube T. When the ether reservoir is rotated till the indicator points to "F," the course of an inspiration will be very different. It will now enter the opening O′, and having passed over the ether (see long arrow), will escape at the opening O into the tube T, and so pass to the patient. The whole of the current will thus become deflected and pass over the ether. An expiration would, of course, travel backwards to the bag by exactly the same route as that by which the inspiration came. The two sectional drawings show the course of an inspiration with the indicator at "0" and "F" respectively. The degree to which the current is made to pass over the ether will depend upon the extent to which the ether reservoir is made to rotate upon the whistle-shaped tube, and this extent is registered by the indicator (*i*). With the indicator at "0" the current is a wholly direct one, passing backwards and forwards to the bag without entering the ether chamber (Fig. 38). With the indicator at "1," one quarter is indirect, *i.e.* passes over the ether, and three quarters are direct, *i.e.* pass to and from the bag without being deflected. With the

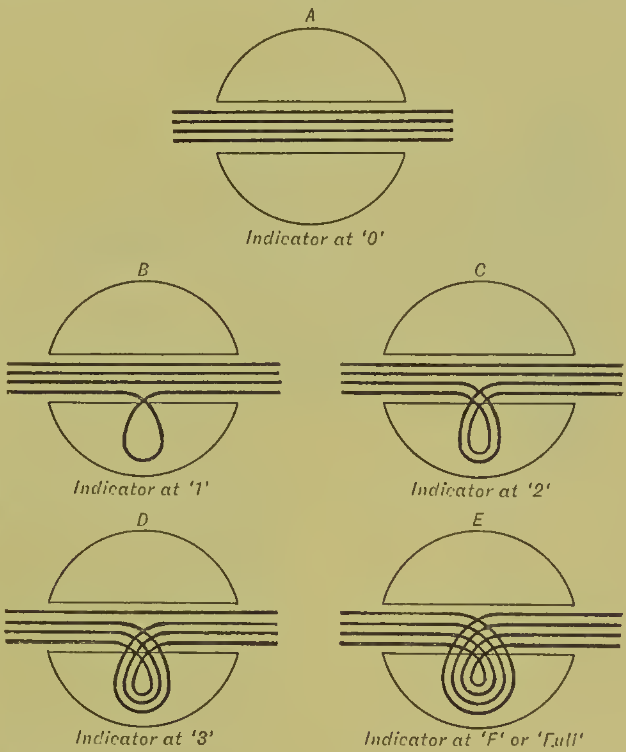


Fig. 40.—Diagram showing the extent to which the air-current passes over ether in Clover's Portable Inhaler when the indicator points to "0," "1," "2," "3," and "F." The whole current is diagrammatically represented by four lines.

indicator at "2," two quarters are indirect, and two quarters direct. With the indicator at "3," three quarters are indirect, and one quarter direct. With the indicator at "F" or "FULL," four quarters (*i.e.* the whole of the current) are indirect, and pass over the ether in the chamber (Fig. 40).

Numerous modifications of Clover's original inhaler have been introduced. Fig. 41 represents a modification which has been constructed for the author by Messrs. Barth and Co. It differs from Clover's original pattern in the following particulars: (1) Its internal calibre or air-way is much larger; (2) instead of the ether reservoir rotating upon the central tube, the central tube rotates within the fixed reservoir; (3) the face-piece is screwed into the ether reservoir, so that these two parts never unexpectedly become separated; (4) the ether reservoir can be adjusted, whatever the position of the patient may be, so that ether may be poured into it through its wide-mouthed filling-tube without removing the face-piece from the face. In order to secure these improvements, it was found necessary to materially modify the internal mechanism of Clover's original apparatus, and to have two separate inner tubes, these revolving as one tube by means of the indicating handle which fits into each. The large bore of the apparatus is distinctly of advantage, not only in lessening the initial unpleasant sensations of re-breathing, but in reducing the asphyxial phenomena (stertor, cyanosis, and laboured breathing) of well-established ether anæsthesia. The apparatus is, moreover, specially useful, and indeed was more particularly designed for administering nitrous oxide and ether in succession (p. 482). The author is glad to take this opportunity of thanking Messrs. Barth and Co., of Poland Street, Oxford Street, W., the makers of this apparatus, for the patience and care with which they have made numerous experimental inhalers for him whilst engaged in perfecting this appliance.

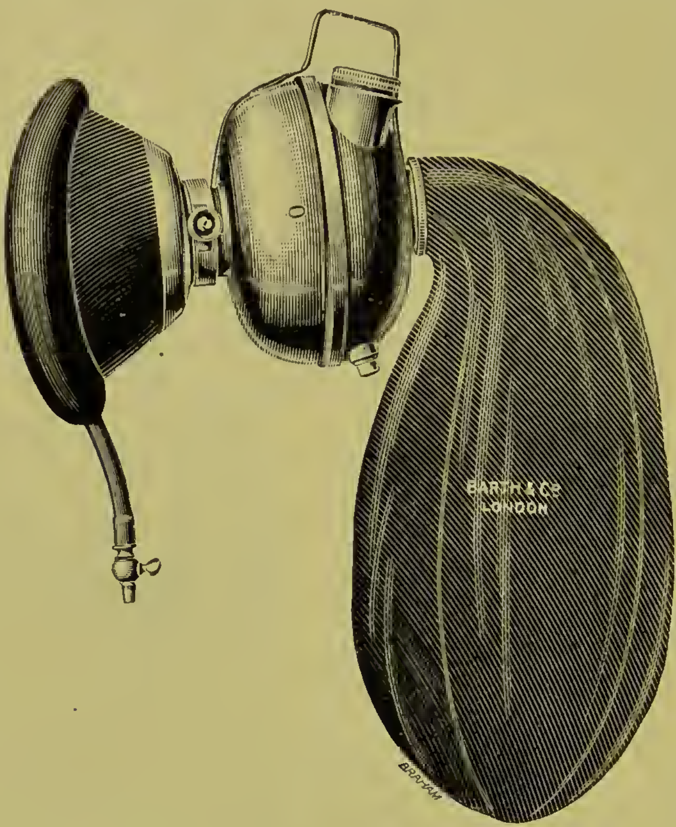


FIG. 41.—The author's Modification of Clover's Portable Regulating Ether Inhaler.

Directions for using Clover's Portable Regulating Ether Inhaler (or any of its modifications)

1. In cold weather, and particularly when about to anæsthetise powerfully-built or alcoholic subjects, partly immerse the ether reservoir in warm water for a few moments.

2. Fit on a face-piece of appropriate size; turn the indicator to "1" or "2" for the escape of air; pour in $1\frac{1}{2}$ oz. of ether; replace the plug; turn back the indicator to "0"; blow once through the apparatus to free its air-way from any trace of ether vapour; and attach the bag.

3. Request the patient to turn his head to one side; instruct him to commence breathing through the *mouth;* and whilst he is doing so, gently apply the face-piece, pressing it rather more tightly during expiration than during inspiration, in order that the bag may become nearly filled with expired air.

4. Allow to-and-fro breathing for about half a minute with the indicator at "0," and see that the bag expands and contracts freely.

5. Very gradually rotate the reservoir or move the indicator so that at the end of the first minute the indicator points to "1," at the end of the second minute to "2," and at the end of the third minute to "3." During the first minute or so the reservoir should be rotated or the indicator moved continuously yet almost imperceptibly. When consciousness has been destroyed, *i.e.* at the end of about $1\frac{1}{2}$ minute, ether may be admitted rather more freely.

6. Any swallowing, "holding the breath," or coughing will indicate that the vapour is too strong, and the indicator must be moved back somewhat till respiration has again become unrestricted. Muscular excitement is very uncommon; should it occur, the administration must be pushed and it will soon subside. In cold weather it may be necessary to expedite vaporisation during the induction stage by applying the hand to the ether chamber.

7. When stertor commences, a single inspiration of fresh air should be admitted by raising the face-piece; and the

administration may then be resumed. The admission of fresh air from this point onwards must be regulated by the susceptibility of the particular patient to this particular process of anæsthetising. As the administration proceeds, more and more fresh air may be given without disturbing the anæsthesia. After the first four or five minutes it is usually advisible to allow one inspiration of fresh air every ten or twelve breaths; after half an hour one inspiration every four or five breaths may be permitted. Stertor, deep cyanosis, rapid and laboured respiration, and especially a strained form of expiration, are the indications for more air. In the case of patients with beards more air gains admission between the face and the face-piece than in other subjects, so that the inhaler must be kept tightly applied during the initial stages, and removed less frequently than usual during the later stages. The anoxæmic factor is almost as powerful as the ether factor in this system of anæsthetising. The less air given the less ether will be needed, and *vice versa*.

8. Some degree of cyanosis is to be expected, especially during the first five minutes. Later on it may be prevented by removing the inhaler for fresh air from time to time.

9. Regular and snoring breathing, insensitive corneæ, and muscular flaccidity are the usual signs that deep ether anæsthesia has been induced.

10. The point at which the indicator should be kept after these signs have appeared must depend, as must the regulation of the air-supply, upon the susceptibility of the patient. As a general rule "F" need only be reached when anæsthetising powerfully-built or alcoholic subjects. Less and less ether will be needed as the administration proceeds, so that at the end of fifteen minutes the indicator may usually be allowed to point to "2" or "$2\frac{1}{2}$," at the end of half an hour to $1\frac{1}{2}$ or "2," and so on.

The above directions apply to the administration of ether to normal adult subjects, and it must be remembered that certain modifications will be needed when dealing with other cases. Strong, plethoric, or alcoholic patients usually require large quantities of ether, and a free use of the anoxæmic factor, in order to obtain good results. On the other hand, children,

feeble, anæmic, and cachectic subjects, and those whose vascular systems are affected by morbid or senile changes will demand careful treatment and the avoidance of any asphyxial strain.

Ormsby's Ether Inhaler

The Ormsby's inhaler usually supplied by the instrument-makers is constructed as represented in the accompanying diagram (Fig. 42). F is a metal (zinc) face-piece which can be bent to any desired shape. Its edge

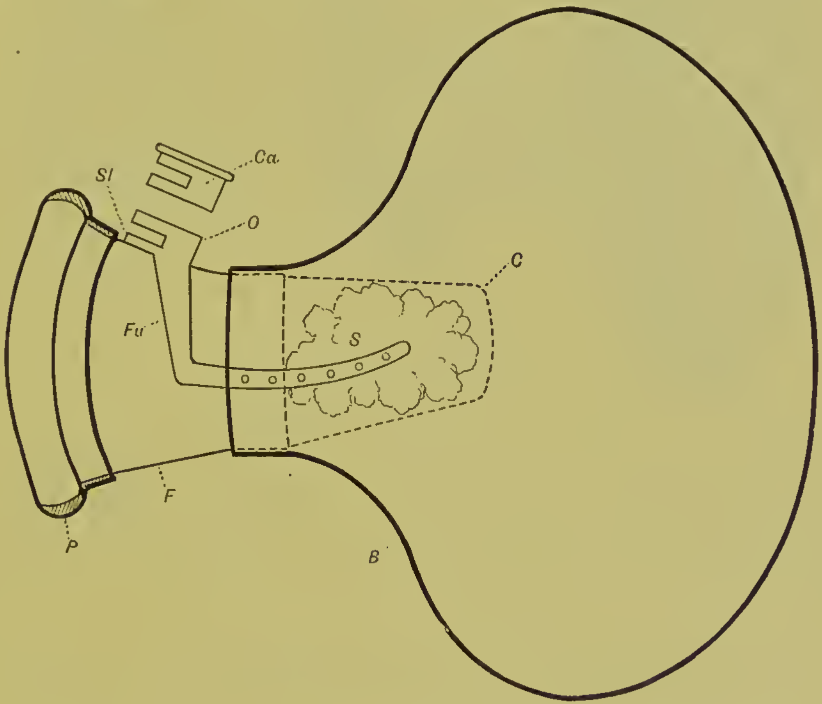


FIG. 42.—Diagram of Ormsby's Ether Inhaler. (Original pattern.)

is guarded by an india-rubber pad (P), which can be inflated with air. To the other edge of the face-piece there is fixed a wire cage (C) containing a sponge (S). The bag (B) fits on to the face-piece, and its neck grasps the cage. The bag is covered with a loose netting by some makers of the apparatus. On the upper surface of the face-piece there is a circular opening (O) with a slot (Sl) cut in its circumference. Fixed into the mouth of this opening there is a funnel-shaped tube (Fu), which passes downwards and then divides, the two arms, which have perforated holes in them, coming into contact with the sponge. A cap (Ca) fits over O, and like O is furnished with a slot, which may be made to correspond to the slot (Sl) in O. When the slots correspond, air will gain admission to the apparatus; when they do not correspond, this communication with the air is cut off. When the cap is taken off, as in the figure, the funnel-shaped tube (Fu) may be used for supplying ether to the sponge.

Experience with this useful inhaler has led to one or two slight modifications in its construction. In actual practice the funnel-shaped filling-tube is rarely used, for it is found to be more convenient to pour ether directly upon the sponge. Then, again, the bag usually supplied with the inhaler has proved to be far too small, especially for anæsthetising patients with full chest capacity. And lastly, any netting over the bag is unnecessary. Mr. Woodhouse Braine, who prefers Ormsby's

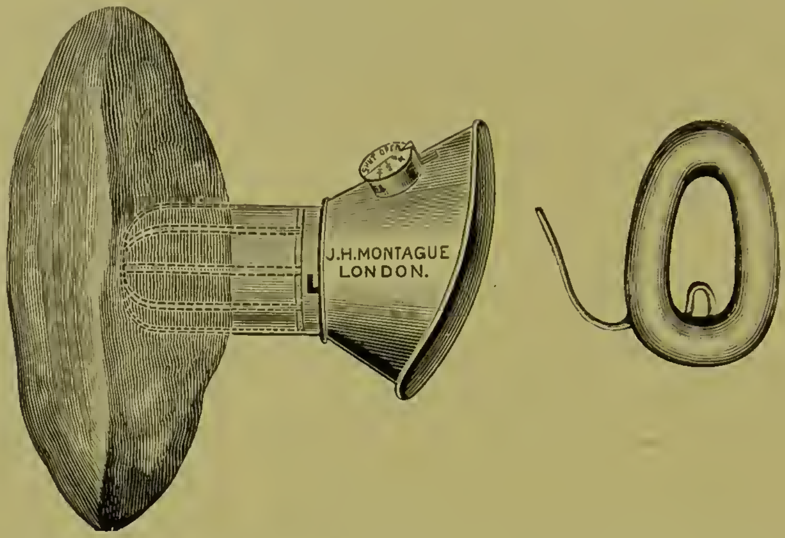


FIG. 43.—Carter Braine's Modification of Ormsby's Ether Inhaler.

apparatus to all others for ether-giving, has therefore used for many years an inhaler possessing no filling-tube and having a capacious bag of red rubber without a network covering. The red india-rubber is little if at all affected by ether.

Fig. 43 represents a modification of Ormsby's inhaler, which has the great advantage that it can be readily cleansed. The cage is made of fenestrated metal, not of wire, and the face-piece pad is detachable.[1]

Directions for using Ormsby's Inhaler

The method which is generally adopted is one of extreme simplicity.

1. Wring out, in hot water, an open-meshed unbleached sponge of sufficient size and insert it in the cage. It should fit well but not tightly.

2. Pour a small quantity of ether upon the sponge.

3. The air-slot being open, very gradually apply the face-piece to the face. At first hold it some little distance off; then bring it nearer and nearer, encouraging the patient to breathe freely.

[1] See *Lancet*, 3rd December 1898.

4. Gradually close the air-slot.

5. Be prepared for the patient attempting to push away the inhaler, rising from the bed, etc. When once the administration has been fairly started, the inhaler should not be removed till signs of anæsthesia are approaching, or till more ether is required.

6. When more ether is needed, about half an ounce at a time may be added to the sponge.

7. From this point onwards the administration must be conducted upon the same principles as those above laid down for etherisation by means of Clover's inhaler.

The following alternative and ingenious method, introduced by Mr. Horace Pechell,[1] has the advantage of more gradually increasing the strength of vapour :—

1. A small quantity of ether is first poured into the bag of the inhaler.

2. A dry sponge is then introduced into the cage.

3. The face-piece is applied with the air-slot open.

4. The air-slot is gradually closed.

5. The ether is then made to moisten a large area of the bag in order to increase the strength of vapour breathed.

6 As the induction proceeds, the bag is gently tilted in order to allow the ether to reach the sponge.

7. Lastly, when once this stage of the administration has been reached, the quantity of ether which should be added to the sponge, and the frequency with which the face-piece should be removed, must be regulated by the principles already laid down.

Whilst Ormsby's inhaler is not so satisfactory as Clover's for *inducing* ether anæsthesia, owing to the fact that ether vapour cannot be so gradually admitted, it is certainly a very excellent apparatus for *maintaining* this state. It is hence a good plan, if Ormsby's inhaler is to be used for ether, to precede the administration of this anæsthetic by ethyl chloride (p. 484) or by a small quantity of the C.E. mixture (p. 487). If, however, such methods be impracticable, the anæsthetist must do his best to reduce, as far as possible, the initial discomforts which must always attend the earlier stages

[1] *Clin. Journ.*, 15th June 1898, p. 155.

of etherisation. The differences in the type of the fully established ether anæsthesia resulting from Clover's inhaler on the one hand, and from Ormsby's apparatus on the other, have yet to be thoroughly explained. On many occasions, whilst administering ether, the author has changed from a Clover's to an Ormsby's inhaler with marked improvement in the symptoms of the patient. He has often known cyanosis to quickly vanish and the breathing to become less hampered by effecting this change of inhalers during deep ether anæsthesia. It is probable that the narrow channels through which the patient has to breathe in Clover's apparatus is responsible for differences of this kind. But there is another possible explanation, viz. that during the intervals in which the inhaler is removed from the face the narrower and more circuitous channels tend to retard diffusion between the bag and the outer air. In Ormsby's inhaler there is greater chance of diffusion, and expiratory products are hence not so likely to accumulate. The large-bore apparatus referred to above (p. 334) was designed with the object of combining, if possible, the advantages of both Clover's and Ormsby's inhalers, and it certainly throws less stress upon breathing, and causes less cyanosis than the ordinary narrow-bore inhalers which have been so long in use. It appears, moreover, to produce less coughing and laryngeal irritation than Clover's original apparatus —an interesting fact considering that the bore is larger. Possibly the ether vapour is more evenly diffused through the inspired air than in the small-bore models.

IV. *The Administration of Oxygen with Ether Vapour*

There is little if any advantage to be gained by this system of anæsthetising, except in certain special cases. We have seen that in vigorous subjects some degree of air limitation is actually advantageous in conducting etherisation. When we pass, however, from the vigorous subject, at one end of the scale, to the exhausted and feeble individual at the other, we have not only to be careful to provide a sufficient supply of air with the anæsthetic, but we may even find it necessary to replace air by oxygen in our administration. Generally

speaking, when respiratory embarrassment is present to such a degree that there is duskiness or actual cyanosis, ether is, as we have seen, contra-indicated. In certain exceptional and desperate cases, however, in which defective blood-oxygenation co-exists with such a degree of cardiac derangement that the risk in giving a general anæsthetic is that sudden syncope may arise from a very slight degree of respiratory embarrassment, ether may be the only permissible anæsthetic, and under such exceptional circumstances as these, the administration is best effected in conjunction with oxygen. The arrangement of apparatus shown in Fig. 44 will be found to answer well. The tubular portion of a small metal funnel is made to pass through a hole at the end of a Rendle's inhaler. To this portion of the funnel a rubber tube from an oxygen bag is attached. A moistened sponge for the reception of the ether impinges upon the expanded portion of the funnel within the inhaler. By keeping up a slow but continuous current of oxygen and by adding ether, in small quantities at a time, to the sponge, a mixture of oxygen and ether vapour is presented to the patient. The author has employed this

FIG. 44.—Arrangement of Apparatus for administering Oxygen with Ether Vapour.

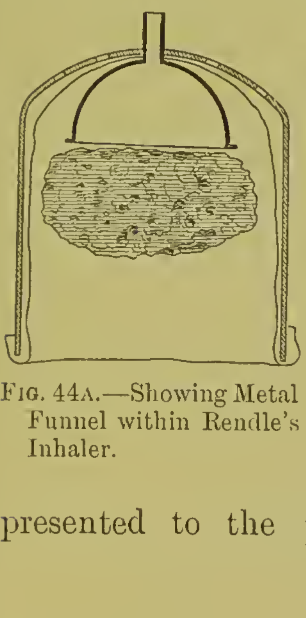


FIG. 44A.—Showing Metal Funnel within Rendle's Inhaler.

arrangement of apparatus with marked success in certain desperate cases of intra-thoracic disease, *e.g.* double empyema, escape of contents of empyema into bronchi, etc., using the C.E. mixture instead of ether.

V. *Rectal Etherisation*

Rectal etherisation seems to have been first suggested by Roux in 1847[1]; and Pirogoff practised it upon the human subject in the same year. The chief object in view was to facilitate the performance of operations within and about the mouth, nose, and pharynx. Liquid ether, sometimes mixed with water, was at first used; but it was soon found that more satisfactory results followed the employment of ether vapour. Within more recent times the practice has been revived by Axel Yversen and Mollière. The latter has given the method a fairly extensive trial,[2] and speaks well of it. He first tried Richardson's hand-bellows for introducing the ether vapour, but afterwards, in five cases, used an india-rubber tube which was connected with a bottle of ether immersed in water at 122° F. The ether vapour was allowed to gradually enter the rectum. As a rule, not more than 2 oz. of ether was used. After 5 to 10 minutes a taste of ether was experienced by the patient, and drowsiness was felt. The rectal administration was supplemented by inhalation if necessary. Excitement was rarely met with. In the same year Dr. Weir[3] published a case in which rectal etherisation proved fatal. The patient was a child of eight months; the operation was for hare-lip. Less than 2 oz. of ether was used. Depression, followed by melæna, supervened, and the child died next morning. Dr. W. T. Bull[4] also published seventeen cases. Melæna occurred in seven of these. Numerous other trials of the system have been recorded.[5] In some of these, profound and prolonged stupor with cyanosis, con-

[1] *Journal de l'Académie des Sciences*, 1847, p. 146.
[2] *Lyon Médical*, 28th April 1884.
[3] *New York Med. Record*, 3rd May 1884.
[4] *Ibid.*, 3rd May 1884.
[5] See *Med. Times and Gaz.*, 7th June 1884 (quoted in *Practitioner*, vol. xxxiii. p. 58); also *Brit. Med. Journ.*, 3rd October 1885, p. 659.

tracted pupils, and asphyxial symptoms occurred. Dr. Buxton has employed rectal etherisation for certain cases, and finds it "to answer admirably for operations about the mouth, nose, and post-buccal cavities, for intra- and extra-laryngeal operations, for staphylorrhaphy, and for operations for the relief of empyema."[1] He has also used the method for operations upon the tongue and jaws with success, and states that the plan gives greater facilities and freedom to the operator than any other with which he is acquainted. He employs an apparatus similar to that of Mollière, and finds that a temperature of 120° F. (for the water round the ether-bottle) answers well. Quite recently[2] Dr. F. H. Cunningham and Dr. F. H. Lakey have recorded 41 successful cases of rectal etherisation. Further experience with the system, however, is necessary. If the risk of diarrhœa, melæna, and after-stupor could in any way be greatly reduced, rectal etherisation would be strongly indicated in certain cases. But as matters stand, the process has too many objections attached to it to warrant us in employing it save in very exceptional cases.

B. THE EFFECTS PRODUCED BY THE ADMINISTRATION OF ETHER

The phenomena of ether anæsthesia will necessarily depend upon the system and method of administration adopted. When the anæsthetic is given slowly and with a free supply of air, *i.e.* by the open system, there will be, as we have already seen, some difficulty in obtaining true anæsthesia, except in very young subjects. When the air-supply is slightly restricted, in other words, when the semi-open system is used, anæsthesia will more rapidly ensue, but excitement and intoxication phenomena will still be liable to manifest themselves. When, however, close methods are adopted patients may be anæsthetised with little or no movement or struggling, for the re-breathing constitutes a powerful factor in the process. Owing to the rapidity and quietude with which patients may be anæsthetised by ether when the air-supply is properly

[1] *Op. cit.* p. 86.
[2] *Boston Med. and Surg. Journ.*, 20th April 1905.

regulated, we do not now, as formerly, have such a favourable opportunity of studying the so-called stages of the inhalation.

First Degree or Stage.—In consequence of the pungent and rather disagreeable odour of ether, it is impossible to completely avoid all unpleasant sensations at the commencement of the inhalation. When well diluted with air, however, or cautiously administered during the re-breathing of a limited quantity of air as by Clover's inhaler, the irritant effects of the vapour will be greatly minimised. Should the vapour be too strong for the particular patient, the glottis will close, as in the early stage of swallowing, and a feeling of suffocation may be experienced. When the anæsthetic is so administered that closure of the glottis, repeated acts of swallowing, and cough are more or less completely prevented, respiration will rhythmically proceed, and will become deeper and quicker than normal. Disturbances of the special senses (p. 84) are common. The pulse is usually considerably accelerated. The pupils are large and very mobile.

Second Degree or Stage.—Loss of consciousness takes place abruptly. The patient passes into a condition in which, although memory, volition, and intelligence are abrogated, he will readily respond to stimuli. The response may have all the appearance of conscious response. Questions may be answered; but the answers will probably be nonsensical. Laughing, struggling, shouting, and singing may be met with at the commencement of this stage if the administration be slowly conducted. Such phenomena are more likely to occur in patients who require considerable quantities of the anæsthetic than in others. Hallucinations of sight and hearing often occur, especially when ether is slowly given with plenty of air. The pupils are still mobile, and usually more or less dilated. The muscular system is for the most part thrown into a state of tonic contraction; but clonic movements may sometimes be witnessed towards the close of the stage. In exceptional cases a fine tremor, known as "ether-tremor," may occur.[1] This

[1] The author has notes of several cases of "ether-tremor." In four of these it was considerable. The ages of three of the patients were 21, 24, and 30 respectively; no age is recorded in the other case. In one instance (the patient aged 30) the tremor came on before the operation commenced. In the patient aged 24, a healthy and well-developed man, undergoing an operation for varicose

phenomenon appears to belong more to the second than to the third stage of etherisation, seeing that it may usually be controlled by a deeper anæsthesia; so that it is referred to here. Mucus and saliva are freely secreted, especially in young and florid subjects. The features become flushed, the conjunctivæ injected, perspiration commences to break out over the face and other parts, and a harmless degree of duskiness, varying with the quantity of air admitted and with the patient's normal colour, will be observed. The pulse is quick and bounding. Any articulate language which may have been uttered becomes replaced by disjointed speech, which in its turn is followed by inarticulate muttering, and subsequently by mere syllables or expiratory noises. The breathing during this stage is inclined to be irregular and a trifle hampered, owing to the tendency to general muscular spasm. Temporarily suspended respiration may thus sometimes be met with, more especially in muscular subjects. The commonest cause for these slight irregularities in breathing at this stage is the employment of too strong a vapour. Clenching of the teeth from masseteric spasm, half-performed acts of swallowing necessarily interfering with respiration, and varying degrees of laryngeal spasm are one and all liable to arise from this cause. As the inhalation proceeds, however, the breathing grows more and more regular, and commencing stertor may be heard. Those muscles whose special office it is to carry on respiration now become incapable of being reflexly affected by the stimulus of ether, whilst others, whose spasmodic contraction would only indirectly affect the rhythm and amplitude of breathing (such as many of the muscles bounding and influencing the conformation of the upper air-passages), are now unable to interfere with free respiration, owing to their having become flaccid under the anæsthetic. In this manner the patient passes into the third stage of anæsthesia.

The reader must bear in mind that when the administration is properly conducted the duration of the second stage is far

veins, the tremor was associated with a very large pupil and some lid-reflex. Julliard (*op. cit.*) states that he has never witnessed this phenomenon in women, and also that the patients in whom tremor occurs are invariably alcoholic or extremely nervous subjects. With the latter statement the author cannot agree, as he has witnessed the symptom in question in young and non-alcoholic patients.

shorter than the above description might suggest. When a close inhaler is used, both the first and second stages may be passed over, and deep anaesthesia reached in from three to four minutes. But for purposes of analysis we have had to picture to ourselves a slow inhalation with more air than is usually advisable.

Third Degree or Stage. — When the respiration has become regular and stertorous, the cornea insensitive to touch, and the extremities flaccid, the patient may be said to have passed into the third degree of anæsthesia, and to be ready for any surgical operation.

The **respiration** during deep etherisation is usually forcible and distinctly audible. Owing to the almost invariable presence of a small quantity of mucus in the fauces and larynx, breathing has a moist character in addition to its usual stertor. A little tendency to spasm of the masseters and adjacent muscles may remain for a while and necessitate the lower jaw being pushed forward from behind (see Fig. 68, p. 529). Such spasm, however, gradually subsides. The anæsthetist must bear in mind that unless he keep up a nearly continuous administration the patient will quickly pass back into the preceding stage, and irregularities in breathing will thus become developed. The rate of respiration is always markedly increased, varying considerably in different cases, and being dependent upon numerous circumstances, foremost amongst which must be mentioned the degree of air-limitation practised. Ether-stertor is most commonly due to the base of the tongue coming in contact with the pharynx, and as breathing usually takes place through the nose the stertor usually has a nasal character. Pushing the lower jaw forwards from behind at once diminishes or stops the snoring. A tendency to laryngeal closure, either from too strong an ether vapour or from operative measures upon certain parts of the body, is not uncommon, but rarely gives rise to difficulty. Sometimes the crowing breathing will persist throughout. When dependent upon the first-named cause, the spasm will subside with less of the anæsthetic; when occurring during rectal or other operations upon sensitive parts, more of the anæsthetic is usually indicated.

The **circulation** of the etherised patient gives numerous clinical indications of its remarkable fulness and force. The heart's action is excited; the pulse is full, bounding, and regular; the face is abnormally flushed; and incised parts, more especially in the neighbourhood of the neck, are very vascular. By means of Leonard Hill's "sphygmometer" it may be demonstrated that the arterial pressure remains constant at its normal level, or falls at most 5-10 mm. of mercury. The pulse, slower than during the second stage, but considerably quicker than normal, is usually from 80 to 110 per minute. It is not uncommon, however, especially in cases in which respiration is greatly accelerated from air-limitation or embarrassed from other causes, for the pulse-rate to be 160 or even more. In one (myxœdematous) patient the author found it 190 per minute during deep anæsthesia, the only peculiarity of the case being that respiration was also very rapid. A roseolous rash sometimes makes its appearance upon the chest, neck, and other parts, when the vascular excitement is at its height.[1] Profuse perspiration is not uncommon.

The **pupils** are usually of moderate size or slightly dilated, *i.e.* from $3\frac{1}{2}$ to $4\frac{1}{2}$ mm., and are active to light. The causes which may influence their size will be dealt with below when discussing the depth of anæsthesia necessary for surgical operations (p. 355). Kappeler found by observations upon 150 cases that the pupils were contracted in 37 during deep etherisation.

The **position of the eyeballs** during deep anæsthesia is similar to that observed under chloroform (see p. 396).

The degree to which the **muscular system** is relaxed will depend not only upon the depth of etherisation, but upon the nature of the operation which is in progress. In some cases a minor degree of rigidity may persist for a considerable time. In several instances the author has noticed that rigidity has passed away with an increase in the quantity of air admitted.

It is hardly necessary to point out that the **colour of the**

[1] Mr. Edgar Willett states (*St. Bartholomew's Hosp. Reports*, vol. xxxii.) that the eruption appears suddenly after three or four minutes' etherisation; that it gradually disappears after two more minutes; that it is most common in women; and that it usually affects the area supplied by the superficial cervical plexus.

face and lips will, during this as during other stages, greatly depend upon the degree to which air is withheld.

C. DANGERS CONNECTED WITH THE ADMINISTRATION

General Considerations

In healthy and moderately healthy subjects the risk connected with the administration of ether is very slight. The fatalities which have been reported have almost invariably taken place in exhausted or markedly diseased individuals.

On looking through the *Lancet* and *Brit. Med. Journ.* for ten years (1880 to 1889 inclusive) the author found 27 fatalities from ether recorded as having occurred in Great Britain during that period. In 24 of these the patients were suffering from various diseases which had seriously impaired their general health. Of the three remaining fatalities, one was so imperfectly reported as to be useless for purposes of analysis; and one could hardly be ascribed to the anæsthetic, seeing that death was caused by vomited matter entering the trachea. The only casualty which occurred solely from ether took place in a patient whose general health was probably though not certainly good, and would most likely have been averted by tracheotomy. The following analysis of the 27 cases may be of interest:—

[Table

TABLE SHOWING THE ETHER FATALITIES reported in the *Lancet* and *British Medical Journal* as having occurred in Great Britain during ten years (1880-1889 inclusive).

Condition of Patient at Time of Administration.	Fatalities.
GROUP 1.—*Patients suffering from some pre-existing morbid state capable of impeding respiration during anæsthesia* .	10
Empyema—2 cases (*B.M.J.*, 13th March 1886, p. 489 ; *B.M.J.*, 22nd April 1882, p. 589).	
Pleural effusion, ascites, dilated heart, and renal disease—1 case (*B.M.J.*, 20th Aug. 1881, p. 327).	
Bronchitis, emphysema, fatty heart, and adherent pericardium —1 case (*L.*, 24th Jan. 1885, p. 178. Also reported in *B.M.J.*, 13th March 1886, p. 489).	
Cancer of lung, liver, and upper jaw—1 case (*L.*, 27th Aug. 1881, p. 386, and *B.M.J.*, 25th Feb. 1882).	
Enlarged thyroid—2 cases (*L.*, 15th Nov. 1884, p. 895, and *B.M.J.*, 2nd May 1885, p. 887 ; *B.M.J.*, 15th March 1884, p. 508).	
Diphtheritic laryngitis—1 case (*L.*, 18th June 1881, p. 1014).	
"Cancerous growth in gums and throat"—1 case (*B.M.J.*, 23rd Feb. 1884, p. 378).	
Extensive pleural adhesion and œdema of lungs—1 case (*B.M.J.*, 18th Dec. 1880, p. 1000).	
GROUP 2.—*Patients suffering from cancerous or other affections producing extreme exhaustion*	10
Intestinal obstruction—3 cases (*L.*, 4th Sept. 1880, p. 376 ; *B.M.J.*, 15th Jan. 1881, p. 103).	
Uncomplicated asthenia—1 case (*B.M.J.*, 13th March 1886, p. 489).	
Feeble patients with abdominal tumours—3 cases (*B.M.J.*, 2nd May 1885, p. 887 ; *B.M.J.*, 15th July 1882, p. 103).	
Asthenia with morbus cordis—2 cases (*L.*, 27th May 1882, p. 892 ; *L.*, 3rd Dec. 1887, p. 1132).	
Large sarcoma of chest-wall, feeble patient—1 case (*B.M.J.*, 1st Jan. 1881, p. 14).	
GROUP 3.—*Patients suffering from renal disease and morbus cordis*	3
Vesico-vaginal fistula (a coloured woman)—1 case (*L.*, 20th April 1889, p. 800).	
Extreme obesity—1 case (*B.M.J.*, 22nd Nov. 1884, p. 1027).	
Diffuse cellulitis of palm and wrist—1 case (*B.M.J.*, 3rd Sept. 1881. p. 414).	
GROUP 4.—*Patients in moderately good health at the time of administration*	2
Sudden cessation of respiration before operation—? cause—1 case (*L.*, 3rd Sept. 1881, p. 430).	
Vomited matters entered larynx and trachea—1 case (*B.M.J.*, 3rd Sept. 1881, p. 414).	
GROUP 5.—*Exhausted patient—ovarian tumour—death from pulmonary congestion seventeen hours after operation* (*B.M.J.*, 2nd May 1885, p. 887)	1
GROUP 6.—*Imperfectly reported* (*L.*, 6th Dec. 1884, p. 1027) .	1
	27

Special Considerations

1. The Administration of an Overdose: Fourth Degree or Stage.—Should the administration of ether be carried too far, respiration will commence to show signs of failure. With this indication of danger the pupils will usually be dilated; the colour dusky rather than pale; the eyelids slightly separated; and the pulse, although still good considering the respiratory depression, somewhat less forcible, and probably slower than it was previously. In some cases the breathing assumes a modified Cheyne-Stokes character.

The manner in which respiratory failure occurs will vary in different cases. In the majority of instances the breathing loses its stertor, becomes feebler and feebler, and then altogether ceases. In some instances, prolonged, difficult, and rather wheezy expiration, with shallow inspiration, may be observed, and may indicate a dangerous depth of narcosis. In others, again, the regular and deep stertor which has been present may be succeeded by jerky, intermittent, and gasping breathing, during which the respiratory movements may abruptly come to a standstill.

An occluded state of the upper air-passages, although possibly occurring in some cases as the result of too large a quantity of the anæsthetic, is more often associated with a light or moderately deep anæsthesia. It is quite conceivable that a falling together or spasm of the arytæno-epiglottidean folds, such as that which Lord Lister has described as arising under chloroform, may result from toxic doses of ether; but evidence on this matter is still needed. Similarly, spasmodic fixity of the chest is probably more frequently associated with incomplete than with dangerously deep narcosis (see p. 552).

The all-important point concerning respiratory failure in moderately healthy patients under ether is that *however such failure may arise, the circulation at the moment when breathing ceases is sufficiently satisfactory for remedial measures to be almost invariably successful.* The heart is not likely to fail unless restorative measures be too long delayed.

2. **Respiratory Failure occurring independently of an**

Overdose.—The respiratory embarrassment which occasionally occurs in connection with the early stages of etherisation rarely gives cause for anxiety. Masseteric spasm, swelling and spasm of the tongue and other structures within the oral and naso-oral cavities, half-performed deglutition movements, laryngeal spasm, and general muscular spasm of the neck, chest, and abdomen may one and all arise during the initial stages of ether administration. By the adoption of simple measures (p. 529) respiratory embarrassment thus arising may generally be quickly corrected. Under certain circumstances, however, it may be difficult or impossible to overcome the spasm upon which the cessation of breathing depends, and it may then become necessary to adopt those lines of treatment (p. 532) which are suitable in such an emergency. Florid, thick-set, short-necked subjects, with accurately meeting teeth, and an inadequate nasal air-way, are particularly liable to respiratory embarrassment of this nature.

Respiratory shock, *i.e.* reflex arrest of breathing from the commencement of surgical procedures during partially established anæsthesia, may arise under ether. This condition has already been fully described (pp. 74 and 252).

Just as there is a liability to temporarily obstructed breathing immediately before deep anæsthesia is established, so there is a chance of its occurrence during recovery, *i.e.* at or about the time that the usual clenching of the teeth and swallowing which precede vomiting are liable to arise.

Respiratory embarrassment from all these causes is always unattended by symptoms of cardiac depression, unless, indeed, the embarrassment has existed for a considerable period, or the patient's general condition is highly unsatisfactory.

3. **Circulatory Failure occurring independently of an Overdose.**—In moderately healthy subjects primary circulatory failure under ether may, for all practical purposes, be regarded as an impossible event. It must be remembered, however, that in *bad* subjects, and especially in those with feeble, dilated, fatty, or otherwise diseased hearts, death may take place under ether with circulatory symptoms. It is true that in most, if not in all of such cases, some slight impairment of or embarrassment to respiration is present, but the patient

dies from cardiac syncope during the slight asphyxial strain. It is in this way that neglected cases of strangulated hernia succumb during the process of etherisation. The "last straw" is furnished by some trivial interference with free breathing, such as that which arises during the stage of struggling or during vomiting.

Circulatory shock, *i.e.* reflex circulatory depression of surgical origin, may be met with under ether, but it rarely assumes grave proportions or threatens life (pp. 76 and 253).

4. **The Passage of Foreign Bodies (Blood, Vomited Matters, etc.) into the Larynx and Trachea.**—For remarks on this subject the reader is referred to p. 539.

5. **Other Dangers.**—Cerebral hæmorrhage has been known to occur during etherisation,[1] but it is of extreme rarity. We must not lose sight of the fact, however, that persons with very brittle arteries run a greater risk of this accident under ether than under less stimulating anæsthetics (see p. 172). There are certain other exceptional conditions which may arise during the use of ether as during the use of other agents: reference will be made to these in Chaps. XVIII. and XIX. The pulmonary and renal complications which occasionally follow the use of ether will be considered below (E. After-effects).

The treatment of the various difficulties and dangers met with under ether is identical with the treatment necessary when such difficulties and dangers occur with other anæsthetics, and it will therefore be considered in Chaps. XVIII. and XIX.

D. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

As a general rule the administrator should endeavour to keep the etherised patient in the third stage of anæsthesia. There is in each case a particular and proper level of narcosis; and, in order that this level may be satisfactorily maintained, the administrator must repeatedly consult certain guides or land-marks which will now be considered. In deciding at

[1] See a case reported in *Amer. Journ. Med. Sciences*, 1888, New Series, vol. xcv. p. 83. See also p. 310.

what place or point we should keep our patient, we must be guided by a variety of considerations. We must bear in mind that, other things being equal, there are certain operations which demand a more profound anæsthesia than others. In the next place, there are some patients whose reflexes are so highly developed that very deep etherisation is necessary in order that good surgical anæsthesia may result. Moreover, after the operation has been in progress for some time, and more especially if much blood has been lost, and the patient is showing even slight signs of exhaustion, we need not maintain that degree of narcosis which was proper at the commencement of the case. By carefully observing the effects produced by more and less ether upon—

(*a*) The respiration;
(*b*) The occurrence of swallowing movements;
(*c*) The lid-reflex; and
(*d*) The pupils,

the administrator will have but little difficulty in deciding upon the precise place or level at which anæsthesia should be maintained. Having once established surgical anæsthesia, he will find that he is able to work in one case almost entirely by the respiration; in another by the occurrence of swallowing movements; in another by the lid-reflex; in another by the pupil; and that a few exceptional cases will remain in which he will have to draw his inferences from all these or possibly from other signs.

(*a*) Of all the guides as to the depth of anæsthesia, **respiration** is by far the most trustworthy. When once surgical anæsthesia has become established, the continued administration of ether will increase the rate, depth, and stertor of respiration, whilst the temporary withdrawal of the anæsthetic will be found to have an exactly opposite effect. A puffing of the lips with expiration is common in deep etherisation. In those cases in which it occurs it constitutes a good guide. In some patients there is an undoubted tendency towards slightly obstructed breathing, more especially when the anæsthesia is not so deep as it should be. This tendency, which is thoroughly discussed on p. 346, must always be borne in mind. It is not a dangerous tendency, because by simply

keeping the lower jaw pressed forwards from behind it disappears. It is most pronounced in muscular and vigorous subjects. In many cases, and more especially in operations upon comparatively insensitive parts, and in protracted administrations, the respiration need not be kept as deep and stertorous as is generally desirable. Sometimes an expiratory moaning sound is made, and may constitute, by its alternate absence and presence, in response to more or less ether, a valuable guide to the administrator. A moist expiratory râle (? laryngeal or tracheal) indicates that less of the anæsthetic should be given; and the same may be said of "strained" or prolonged expiration.

(*b*) The act of **swallowing**, easily recognised by placing the fingers over the larynx, is sometimes the first indication that the patient is emerging from deep anæsthesia, and when it occurs the administrator should at once give a little more ether, in order to avoid the coughing, straining, and vomiting which may follow.

(*c*) The **lid-reflex**, *i.e.* the closure of the eyelid when the conjunctiva or cornea is touched by the finger, although regarded by many as an untrustworthy guide, is in the author's experience a most valuable indication of the depth of anæsthesia. In order that it may be properly made use of, the administrator must remember three facts. In the first place, it very commonly happens that, although no lid-reflex can be elicited by touching the margin of the lids or the conjunctiva covering the sclerotic, a brisk closure will follow the application of the finger to the *cornea*. In the next place, the conjunctiva, by being repeatedly touched, loses its sensibility. And lastly, there are degrees of this reflex, so that the patient may require to be kept at a stage of anæsthesia bounded on the one side by considerable and on the other by very slight lid-reflex. It is sometimes easier to feel than to see a minor degree of lid-closure in response to touch. Moreover, when from having frequently touched the conjunctiva of one eye its sensibility has become diminished, the other eye may be tested. It is a good plan, indeed, to keep one conjunctiva, as it were, in reserve. Whether or not the administrator should allow the lid-reflex to be present must depend upon the behaviour of

the patient when he is permitted to display a slight degree of this reflex. Generally speaking, the lid-reflex should be kept in abeyance, especially during operations upon sensitive parts, and in patients whose reflexes are highly developed. In anæmic and weakly subjects, and towards the end of long operations, lid-reflex may usually be allowed, and will be found to be perfectly compatible with satisfactory anæsthesia.

(*d*) If carefully watched and studied, the **pupil** will, in most cases, afford valuable information. It will be of little service as a guide until after about a quarter of an hour from the beginning of the administration. The anæsthetist should then watch its behaviour with more and less of the anæsthetic, and he will usually have but little difficulty in deciding what size of pupil indicates proper anæsthesia in the case before him. We have already seen that the average pupil of deep etherisation is one of moderate size ($3\frac{1}{2}$ to $4\frac{1}{2}$ mm.); but in some patients a smaller, and in others a larger may be seen during satisfactory narcosis. The anæsthetist will usually observe that if he give less ether, the proper pupil of the particular case will become smaller; if he increase the depth of etherisation it will grow larger. He may find, for example, that if he allow a pupil of 4 mm. to come down to 2 or $2\frac{1}{2}$ mm., the patient will commence to swallow, strain, or show indications of cough. The pupil does not, however, always diminish in size in response to less ether, and increase in size in response to more. The matter is complicated by the frequent tendency of the pupil to grow large from reflex irritation caused by surgical or other procedures. This tendency is more marked when a light anæsthesia is maintained. Should this tendency to reflex dilatation be present, we can readily understand that it would be checked; in other words, the pupil would grow smaller by *more* of the anæsthetic. Neurotic and anæmic subjects, as well as children, not unfrequently exhibit a great susceptibility to reflex dilatation of the pupil throughout. In old people, on the contrary, and in those whose reflexes are not so highly developed, the pupil is less likely to fluctuate in size, and is usually smaller. This reflex enlargement of the pupil may be distinguished from what we may call the true toxic dilatation by observing the effects of more and less of the anæsthetic upon it. Suppose, for

example, that the patient is undergoing an operation, and that his pupils are 5 mm. The question will arise: Are these pupils of reflex origin, or are they due to a deep anæsthesia? The problem may perhaps be solved by consulting the lid-reflex and other guides; but it may be more certainly settled by observing whether the pupil grows smaller or larger with less ether. If it become smaller with less ether the previous dilatation was probably due to a very profound anæsthesia; if it become larger with less ether the previous dilatation was probably of reflex origin. These considerations explain the apparent anomaly of an increased quantity of ether producing in one case a larger and in another a smaller pupil. Carrying the matter one step farther, the reader will see that, supposing the patient to possess a pupil of 5 mm., and the dilatation to be of reflex origin, more ether will first of all bring the pupil down to, say, $3\frac{1}{2}$ mm., and then, should the administration be continued, will cause the pupil to again dilate to 5 mm.; but this latter dilatation will be the toxic dilatation. The progressive diminution in the size of the pupil, which may often be observed in a long operation, is probably due to the progressively lighter anæsthesia and the more liberal supply of air which are found to be permissible. Finally, we must bear in mind the fact, when considering the pupil under ether, that any marked deprivation of oxygen will tend to effect an additional increase in size.

E. AFTER-EFFECTS

As a general rule, distinct signs of **recovery** from etherisation should be evinced soon after the withdrawal of the anæsthetic. As pointed out (p. 596), recovery will take place more speedily and satisfactorily when the patient is placed upon his side. Ether is often given in unnecessarily large quantities, the patient being saturated, as it were, with the drug. A prolonged stupor, unattended by cough, and characterised by slight duskiness and deterioration of pulse, may follow this injudicious and excessive use of ether. A minor degree of duskiness after this anæsthetic is not uncommon, and is usually connected with the presence of mucus

in the air-passages, and with the quieter breathing following the withdrawal of ether. Directly coughing or retching has occurred, the patient's normal colour will become restored.

Ether generally leaves behind it a somewhat disagreeable **taste**, whilst its **odour** may be detected in the breath for a considerable time after the administration. Provided the patient has been properly prepared, that the administration has been skilfully conducted, that the purest ether has been used, that the patient has been placed in a proper posture after the operation, and that the inhalation has not been very protracted, there will usually be but little trouble from **nausea, retching, or vomiting.** Transient retching, with the expulsion of a small quantity of colourless or yellowish fluid, is the rule rather than the exception. This so-called "vomiting" after ether is almost characteristic of the use of the drug. It comes on soon after the anæsthetic has been discontinued; it is violent for the moment; and it rapidly subsides, leaving the patient either dazed, half conscious, and looking about him, or still unconscious and in a quiet sleep. As a general rule, ether-vomiting takes place and is passed over whilst the patient is still unconscious, although repeated attacks are not uncommon, especially after lengthy administrations, and in certain subjects, *e.g.* those with habitual naso-pharyngeal or nasal catarrh.

Clover met with vomiting once in every 7 or 8 cases, but it is probable that minor cases of nausea are not included. Julliard observed it in 314 out of 3654 ether administrations (= 1 in 11 or 12). He does not state, however, whether he includes cases of transient ether nausea. Probably he does not. Jacob of Leeds (*Lancet*, 11th Oct. 1879, p. 539) recorded 1200 cases in which he used ether. He states that in no case was there severe vomiting. One patient in every five vomited before leaving the theatre, and a few others vomited afterwards. Rigden (*Lancet*, 31st Oct. 1874, p. 620) took notes of a considerable number of ether administrations, and met with vomiting in 50 per cent of the cases, but in 35 per cent it was very slight. It was noted as considerable in 15 per cent. He found that the vomiting after ether lasted a shorter time than that after

chloroform. Fausset (*Lancet*, 18th June 1892, p. 1386) found that, putting aside abdominal sections, 47 out of 68 (= two-thirds) of the etherised patients at the Chelsea Hospital for Women vomited after the operation. In 21 cases (= one-third) no vomiting occurred. In 21 abdominal sections 18 vomited after ether. But it does not appear that *pure ethylic ether* was used for the administrations. Körte (*Deut. med. Zeit.*, 12th Feb. 1894) met with vomiting 60 times in 300 cases, or in one-fifth; but morphine was used in conjunction with the ether. Blumfeld (*Lancet*, 23rd Sept. 1899) met with an absence of after-sickness in 112 cases out of 501 administrations of "gas and ether."

On several occasions the author has met with **hæmatemesis** after ether.

The patients, have, as a rule, been in good condition, and partly by reason of their physique and partly from the nature of the operation it has been necessary to keep up a very deep anæsthesia. As a general rule, too, the patients in whom the hæmatemesis has arisen have not taken ether as smoothly as most cases, displaying jaw-spasm, cough, tendency to retch, etc. In one case—that of a florid boy of twelve—a persistent tendency to vomit occurred throughout the administration. Ether was first of all given, but after five minutes chloroform was substituted. The fluid which was then ejected contained no blood; but at the end of half an hour's deep chloroform anæsthesia hæmatemesis came on. The author has seen other cases in which this symptom has arisen after the ether-chloroform sequence. He has also met with one case in which it occurred after the A.C.E.-chloroform sequence. The patient was a bad subject of sixty-six, suffering from senile dementia, chronic bronchitis, and cardiac disease: lithotrity was performed quite successfully: hæmatemesis came on after the operation, but gradually subsided. In the majority of the author's cases the operation has been for the radical cure of hernia. The vomited material has either been porter-coloured or so similar to undigested beef-tea that its true nature has not been suspected. In one or two of the cases he has had the ejected fluid examined by competent authorities, who have confirmed his opinion as to its nature. The hæmatemesis is probably capillary or congestive. The author has never known it give rise to any subsequent trouble or to recur to any serious extent. In one case at the London Hospital (which was under the care of Mr. Mansell Moullin) the patient, who had a gastric ulcer, was seized with hæmatemesis whilst under ether. It was thought advisable to suspend the operation at the time; but as a subsequent attack took place, the patient was again anæsthetised, the stomach opened, and the ulcer successfully treated.

Hæmoptysis is rarely met with. The author has only

seen one case during twenty years' practice, and in this the hæmorrhage was slight and soon subsided.

Until quite recently, opinions were divided as to the reality of **respiratory complications** after ether; but it may now be regarded as an established fact that whilst this anæsthetic is an exceedingly safe one so far as the administration period is concerned, its use is not unfrequently followed by bronchial and pulmonary sequelæ. Several years ago Dr. Jackson, Dr. Saundby, and the late Mr. Lawson Tait [1] drew attention to these respiratory after-effects. In 1898 Dr. David Drummond [2] published eight interesting cases of **ether-pneumonia**, two of which proved fatal.

In seven out of eight of these cases the temperature rose at the end of the first twenty-four hours following the operation to 101° or more. In no case was the disease lobar in its type. Fortunately there were post-mortem examinations in the two fatal cases, and distinct signs of lobular pneumonia were found. In the six cases which recovered, abdominal operations had been performed, and Dr. Drummond thinks that the presence of a painful abdominal wound may, by its preventing cough and expulsion of mucus, favour the broncho-pneumonic process.

As mentioned in the previous edition of this work, several cases of **ether-bronchitis** and **ether-pneumonia** occurred at the London Hospital during a period of 5 years, in which special notes were taken as to the frequency of these conditions.

In one instance, the patient, who had had no previous chest affection, so far as could be ascertained, was seriously ill for several weeks, and eventually left the hospital with a crippled lung. In another the pneumonia proved fatal.

In 1902 Mr. H. C. Crouch and Mr. E. M. Corner in an interesting and valuable communication [3] corroborated the work of others in this direction, and established the fact, beyond all question, that ether anæsthesia has a special tendency to be followed by **respiratory complications**.

These observers analysed the records of 3000 administrations of ether, chloroform, and other anæsthetics at St. Thomas's Hospital in 1900. Of these 3000 cases there were at least 10 in which bronchitis and broncho-

[1] *Birmingham Medical Review*, May 1894.
[2] *Brit. Med. Jour.*, 1st Oct. 1898.
[3] *Lancet*, 24th May 1902, p. 1457.

pneumonia arose within 24 hours after the administration, the patients having displayed no evidences of these conditions beforehand. In all these 10 cases ether preceded by nitrous oxide was used. The ages of the patients varied from 9 to 62. The operations were all lengthy: colotomy, (1); "Whitehead," (1); for inguinal hernia, (2); for pyonephrosis, (1); for radical cure of hernia, (2); for varicose veins, (1); for amputation of breast, (2). In 6 cases there was bronchitis; in 2 there was broncho-pneumonia; in one there were bronchitis and pleurisy, and in one (fatal) bronchitis, broncho-pneumonia, and pleurisy. It will be observed that, with one exception, the operations were upon the trunk.

Dr. G. E. Armstrong[1] of Montreal has published some **statistics** which are interesting in this connection.

Of 2500 ether administrations at the Montreal General Hospital in the years 1902 to 1905, 55 or 2·2 per cent were followed by lung complications within 48 hours after anæsthesia. The patients' ages ranged from 1 to 78 years. Ether appears to have been used in certain cases for which this anæsthetic is generally regarded as unsuitable. Clover's inhaler was, as a rule, employed. Of the 55 cases, considerably more than half (*i.e.* 35) occurred in the five winter months. In 37 of the 55 cases, a septic focus in some part of the body was present before the development of the lung complications. The 55 cases comprise: 14 of lobar pneumonia; 16 of broncho-pneumonia; 19 of acute bronchitis; and 6 of pleurisy. Of the 2500 ether administrations 39 were for trephining, and of these 39 cases, 8 or 20·5 per cent developed lung complications. This high percentage in the trephining cases is to be explained by the fact that, as many of the patients were semi-comatose, nourishment and vomited fluids entered the air-passages. Of 952 abdominal operation cases, 27 or 2·8 per cent developed lung complications. Dr. Armstrong believes that the greater frequency of *right-sided* lobar pneumonia which was observed, supports the view that these inflammatory lung complications are due to the invasion of septic matter from the mouth and pharynx rather than to infection through the blood and lymph.

In certain cases ether causes the secretion of so much **tracheal and bronchial mucus (bronchorrhœa)** that a condition results to which the term "**mucus-inundation**" may perhaps be appropriately applied. This condition is sometimes termed "**acute pulmonary œdema**," but it would be more correct to restrict the use of the latter term to cases of a somewhat different type (see Illust. Case, No. 9). In the two following cases, one of which the author has taken from the *Transactions of the Society of Anæsthetists*, the other having been reported to him by a well-known anæsthetist, fatal asphyxia appears to

[1] *Brit. Med. Jour.*, 19th May 1906.

have resulted from the presence of excessive mucous secretion within the bronchi.

Illustrative Case, No. 7.—F. æt. 30. Married. Has lost weight for three months. Pale. Cachectic-looking Heart and lungs normal. Pulse 72, regular and strong. Urine contains trace of albumin. Exploratory abdominal section. Ether administered by Clover's inhaler. "During the period of induction the index never exceeded two, and throughout the operation stood at one or a little under." Went under quietly in about 3½ minutes. No coughing or laryngeal spasm. No conjunctival reflex. Respiration free and unimpeded. Pulse full, soft, and regular. Towards end of operation some cyanosis and *a good deal of frothy mucous secretion.* Operation lasted 65 minutes. Patient transferred to trolly. Still somewhat cyanosed. Breathing rather shallow and sighing. Pulse 120, of good quality. Conjunctival reflex present. Pupils equal and contracted. Five minutes later pulse 134, regular, and of good quality; "respiration unimpeded though shallow"; cyanosis still present; conjunctival reflex still present. Ten minutes after operation over, a sudden change in colour was observed, the cyanosis being replaced by a "ghastly ashy-grey colour"; pulse suddenly became "bad," and after one or two sighing respirations, breathing ceased. Head lowered and artificial respiration commenced, the tongue being drawn out by forceps. Strychnine, brandy, and oxygen administered. Interrupted current applied to præcordium. Pulse absent at both radial and femoral arteries: no heart sounds audible. Artificial respiration kept up for 40 minutes, but without success. *During the performance of artificial respiration a large quantity, estimated to have been at least a pint, of frothy, watery secretion came away.* In all slightly over 4 oz. of ether used. The ether was analysed and found to be of sp. gr. ·720. Ether from the same bottle had been used for other patients without any ill effects. *Post-mortem.*—Liver and kidneys healthy though engorged with blood. Spleen small. Upper lobes of both lungs slightly emphysematous. Lower lobe of right side tough and contains very little air. "The rest of both lungs is saturated with frothy fluid which pours out of the bronchial tubes on pressure. The bronchi themselves are healthy. There are no signs of stomach contents in the air-passages and the fauces are clear. The heart is of normal size and proportions; the right side cavities are full of blood." Heart muscle apparently healthy. All valves competent. No signs of embolism or thrombosis in pulmonary vessels. Brain engorged with blood but healthy.

It is, perhaps, hardly right to express an opinion upon a case which one has not had the opportunity of observing, but from the foregoing notes it is probable that the following factors led to the fatality. (1) The patient was of a type requiring moderate rather than deep anæsthesia and the avoidance of undue air-limitation; (2) ether produced much

mucous secretion, which became churned up, thus increasingly filling the small bronchi; (3) the heart muscle gradually became poisoned by oxygen starvation and carbonic acid retention; and (4) asphyxial syncope followed. The post-mortem records strongly support this view.

The following remarkable case, which is similar in many respects to the foregoing, occurred in the practice of Mr. E. F. White of Putney, and the author is greatly indebted to him, as well as to the anæsthetist who was in attendance, for notes of the case.

Illustrative Case, No. 8.—F. æt 32. Lungs and heart normal. No previous history of chest affection. Operation for ruptured perineum of some years' standing. Lasted nearly an hour. Weather fine and hot. Ethyl chloride-ether-chloroform sequence. 4 c.c. of Duncan and Flockhart's ethyl chloride; pure methylated ether of sp. gr. ·720 administered by Bellamy Gardner's inhaler; Burroughs Wellcome's chloroform, with definite percentage of ethyl chloride administered by Vernon Harcourt's inhaler. Induction quiet and normal. No spasm or cyanosis. After about a quarter of an hour chloroform was substituted for ether, as the latter had produced some "bubbling of mucus." Chloroform "taken easily, and the mucus, although somewhat freer than usual, diminished." No cyanosis was observed either by administrator or operator. The depth of anæsthesia was "of the ordinary third degree." "The pupil remained fairly contracted throughout. No reflex movements. No coughing or retching." At the conclusion of the operation patient breathing quietly with good pulse. She became conscious and spoke before surgeon left. Vomited twice and coughed slightly. Cyanosis began about half an hour after patient put back to bed. "The symptoms seem to have come on gradually, the lungs slowly completely filled with fluid." Three hours after beginning of operation she was "bringing up frothy blood-stained mucus," with much cough, increasingly rapid breathing (about 40 per minute), and pulse 150. This state lasted for about two hours. *Chest Examination.*—No dulness; air entering tubes; a large amount of mucus crepitation over both lungs; heart much dilated (*sic*). The face was livid; blood-stained mucus was coughed up for some time; then all cough ceased. "Patient quite conscious and recognising her suffocating condition until she dropped back dead 12 hours after operation." The ether used had been employed for other cases without ill effect.

Here again one is hardly justified in expressing any very definite opinion. It would seem probable, however, (1) that ether produced an excessive secretion of mucus; (2) that this mucus was not expelled by cough and that it hence increased by becoming churned up and aerated; (3) that the change to

a chloroform apparatus *of the suction type* increased the tendency to an asphyxial state; and (4) that asphyxial syncope finally ensued. This case is included in the present chapter because the mucus-inundation which caused the death of the patient was produced by ether.

Although it is difficult in the present state of our knowledge to draw any hard and fast line between mucus-inundation on the one hand and so-called **acute pulmonary œdema** on the other, the latter term would seem to be most appropriately applied to cases of the following type, and not to those in which asphyxia is brought about either by excessive mucous secretion, as in the two foregoing cases, or by the entry of vomited fluids into the trachea and bronchi, as in the case referred to on p. 543. The subjoined case occurred during the author's term of office at the London Hospital, and is one of considerable interest.[1]

Illustrative Case, No. 9.—The patient was a male of fourteen years of age. About three months before admission he contracted typhoid fever and the attack was a severe one. He subsequently developed symptoms of appendicitis and was admitted to the hospital on 5th January 1897, to be operated upon for that affection. On 15th January, the day of operation, the boy appeared to be in very fair health; he had good heart sounds, there was no cough or difficulty in breathing, and the abdomen was not distended. Ether was given to him by means of a Clover's inhaler, and the administration lasted forty minutes. The induction of anæsthesia was perfectly smooth and there was no difficulty of any kind, but when the patient was fully under ether I noticed a great peculiarity about his breathing. The abdomen, instead of rising with inspiration, as is usual, receded, and respiration was wholly thoracic, although a plentiful supply of air was allowed. Slight cyanosis persisted throughout. No other abnormality noticed. Pupils moderately contracted. No abnormal secretion of mucus. Later in the day it was noticed that more mucus than usual seemed to be present in the air-passages; that the respiration was 32 per minute; and that the pulse was 112. The breathing did not improve during the night. Patient slept fairly well, but complained of pain at base of left lung anteriorly. At 8 A.M. next day, pulse 160; respiration 40; a good deal of "rattling" in the chest, at 12 noon the breath sounds were harsh with râles and rhonchi all over the chest, except at the base of the left lung anteriorly, which was dull to percussion. The heart sounds were almost indistinguishable. There was no increase of vocal resonance. The apex beat of the heart was not displaced. There was no sign of fluid or definite

[1] This case was published in the *Lancet*, 19th March 1898, p. 772.

pneumonia. The respiration was 52. Stimulants were given, the inhalation of oxygen was employed, and the patient was propped up in bed. At 4 P.M. the respiration was 81, the pulse was 150, and the temperature was 102° F. At 10 P.M. the patient grew very dusky and he was bled, but only one and a half ounces of blood issued. No tubular breathing was audible, but both bases posteriorly were dull and the breath sounds were deficient. Strychnine and digitalis were injected every two hours, but there was no improvement, and the patient died thirty-four hours after the operation. Unfortunately no post-mortem examination was allowed, but everything seems to point to acute pulmonary œdema as the cause of death.

It is in the highest degree probable that in the above case the complete absence of diaphragmatic breathing led to fatal basic engorgement of the lungs.

There is yet another class of respiratory complication to which reference must here be made, although it is questionable whether the anæsthetic is in any way accountable.

Dr. Henry Menzies, late anæsthetist to St. George's Hospital, has kindly furnished the author with notes of certain cases which he brought before the St. George's Hunterian Society in 1901 with the object of proving that so-called "ether-pneumonia" is frequently a local pleuro-pneumonic condition brought about by pulmonary emboli which have entered the blood-stream at the site of operation. There were five cases in all. The operations were for hernia (4) and varicocele (1); the patients were all males. There was no uniformity as to the time at which the symptoms arose after the operation (12 hours to 7 days). Sudden pain in the chest, elevation of temperature, cough, and quick pulse and respiration, were generally observed. Evidences of fluid were subsequently noticed. Blood-stained sputum was noted in one case. There was but little constitutional disturbance. All patients recovered.

Whether **pulmonary infarction** such as occurred in these cases is more likely to arise after ether than after other anæsthetics is at present uncertain. The fact that in all Dr. Menzies' cases ether was used (in one chloroform was given after ether) is suggestive.

It is obvious from the foregoing evidence that the use of ether as a routine anæsthetic specially predisposes to the occurrence of respiratory after-effects. It is also obvious that these after-effects may differ considerably in their nature and intensity. Unfortunately, we are still somewhat in the dark as to their immediate causation and pathology. It is highly probable that more than one factor is usually present. It can

hardly be contended that cutaneous exposure, incautious ventilation, or the conveyance of patients through draughty corridors can have any very great share in the production of these sequelæ, seeing that when other anæsthetics have been employed they are rarely if ever met with. It would seem that the hyper-secretion of mucus, which is almost characteristic of ether anæsthesia, is the chief factor with which we have to reckon in most cases of ether-bronchitis and ether-pneumonia. Doubtless patients with pre-existing bronchial, pulmonary, or pleural disease, if anæsthetised by ether in contravention of well-established principles, are more liable than others to this excessive mucous secretion and its consequences. But the above data indicate that even in the most healthy subjects this hyper-secretion of mucus has its special risks, and that these risks increase when, as in abdominal cases, coughing is rendered difficult or impossible during the recovery period. In addition to these factors the duration of etherisation doubtless has its influence. Thus, after a comparatively short administration the air-passages, even though considerably blocked by mucus, will generally be cleared by cough before the patient regains consciousness. After prolonged etherisation, however, the reflexes may remain blunted for a comparatively long period; the withdrawal of the re-breathing stimulus causes quiet respiration; and the result is that the smaller bronchi tend to become more and more invaded by the frothy mucus. Minor degrees of bronchial catarrh are by no means uncommon after protracted etherisation, and the step from a bronchitic to a broncho-pneumonic state is very easily effected, the catarrhal process extending to the alveoli, or the latter becoming inflamed as the result of mucus-blocking within the bronchi. As regards the condition to which the term mucus-inundation has been applied, this would seem to be most likely to arise when deep anæsthesia is maintained for some time by means of a close inhaler in a patient in whom ether has produced much frothy secretion. In addition to the factors just mentioned others doubtless come into play in some cases; *e.g.* excessive air-limitation during etherisation, the adoption of a particular posture for a protracted period during or after anæsthesia, so that mucus-plugging and hypostatic congestion are favoured,

the passage through the larynx of blood, septic matter, or vomited fluids, and weak cardiac action favouring pulmonary stasis. It is quite conceivable, too, that the use of imperfectly cleansed inhalers (p. 260) may favour the occurrence of ether-pneumonia. Most of these factors, however, may come into play with other anæsthetics, so that their influence need not be discussed here. For further information the reader is referred to the final chapter of this work, in which the preventive treatment of respiratory after-effects in general is fully considered.

With regard to the frequency of **renal complications** after ether it is difficult to speak with certainty, owing to the fact that the statements made by those observers who have specially studied this point are very conflicting. The author has not, to his knowledge, met with any cases in which such complications have occurred; but it is only fair to say that the anæsthetist's opportunities for ascertaining the condition of patients after anæsthesia are very limited. It is contended by some writers that there is a greater risk of renal symptoms arising after ether than after chloroform; that this risk is increased in the case of patients with previously damaged kidneys; and that complications of this character are most likely to arise when the anæsthetic has been unnecessarily pushed. It must be remembered, however, that patients with pre-existing albuminuria are constantly being subjected, in our hospitals and elsewhere, to ether narcosis without any unfavourable after-effects arising.

Dastre,[1] Fueter,[2] and Roux[3] have urged the infrequency of these complications. Weir met with after-albuminuria in 9 out of 34 ether administrations, the patients having been free from this symptom prior to the anæsthesia. Wunderlich,[4] who studied 125 cases of ether and chloroform anæsthesia, found albuminuria *less* common after ether than after chloroform in non-albuminuric subjects; whilst in those in whom albuminuria pre-existed, ether augmented the condition. Barensfeld[5] met with two cases of albuminuria (one being very marked) in 150 ether administrations to non-albuminuric subjects, and failed to find any increase of albumin in two patients with pre-existing renal

1 *Op. cit.*
2 *Klinische und exper. Beobachtungen über die Aether-narkosa*, p. 28.
3 Julliard, *op. cit.*
4 *Annals of Surgery*, May 1894, p. 630.
5 *Year-Book of Treatment*, 1896, p. 174.

symptoms. In 500 non-albuminous subjects to whom ether was given, Butler[1] met with one case of albuminuria; while Kute in 600 such administrations noted six cases. Ogden[2] found that albuminuria appeared in a considerable percentage of etherised patients whose urine was previously non-albuminous. Kemp quotes hospital statistics and brings forward other evidence in support of the frequency of dangerous renal complications after ether, believing that about 5 per cent of ether cases prove fatal from such complications.[3] On the other hand, Buxton and Levy[4] are unable to satisfy themselves that ether, when properly administered, exerts any unfavourable influence upon the kidneys. The researches of Drs. H. Pringle, Maunsell, and S. Pringle have already been considered (p. 104).

During the last few years certain cases have been recorded in which a peculiar condition known as **acid-intoxication** or **aciduria** has appeared after the use of anæsthetics. This complication, which seems to be far less common after ether than after chloroform, will be considered in the final chapter of this work (p. 604).

Transient **mental and muscular excitement** may arise after ether, and is more particularly liable to do so in hysterical, neurotic, or alcoholic subjects who have been but a short time under the anæsthetic. In very rare instances **mania** and **dementia** have been recorded.[5] Choreiform movements lasting three weeks have also been reported.[6]

As stated above (p. 172), there is a slight but distinct risk of cerebral hæmorrhage occurring during the etherisation of certain subjects, and, as a result, **hemiplegia** may follow. A case of this kind occurred some years ago at the London Hospital.[7]

Lastly, there is some evidence that ether anæsthesia

[1] *Gould's Year-Book*, 1897, p. 246.

[2] *Year-Book of Treatment*, 1898, p. 165.

[3] See also *Annals of Surgery*, vol. vi. p. 327; *New Orleans Med. and Surg. Journ.*, 18th Aug. 1887; *Brit. Med. Journ.*, 2nd June 1883, p. 1082; *New York Med. Journ.*, 1st March 1890; *Canadian Practitioner*, Feb. 1888; *Chicago Med. Journ. and Examiner*, May 1888; *Med. Register*, 4th Feb. 1888; *Journ. Amer. Med. Assoc.*, 5th May 1888; *Brit. Med. Journ.*, 11th Nov. 1899; p. 80 (Epitome).

[4] *Brit. Med. Journ.*, 22nd Sept. 1900, p. 833.

[5] See Dr. Savage's paper, *Brit. Med. Journ.*, 3rd December 1887, p. 1199; also *Boston Med. and Surg. Journ.*, August 1889; also *American Journ. Insanity*, Utica, April 1890. For further remarks on the subject see p. 367.

[6] See Dr. Jacob (*Lancet*, 16th October 1879, p. 539).

[7] The patient was a somewhat elderly man. Clover's inhaler was used. Although the history was not forthcoming before the operation, it was eventually ascertained that there had been a previous apoplectic seizure with complete recovery.

predisposes to **thrombosis.** Some years ago the late Dr. Moxon[1] reported a case in which, according to his view, a thrombotic state of a branch of the coronary artery was brought about by the administration of ether (for a rectal operation). The patient regained his health, but three weeks subsequently sudden death took place, the only discoverable cause being a slight recent extension of the thrombosis into the main vessel, so that a large area of cardiac muscle suddenly became deprived of its blood supply. Reference has already been made (p. 243) to a case of (?) cerebral thrombosis following prolonged etherisation in the Trendelenburg posture. The cases of pulmonary infarction after ether are also suggestive of this thrombotic tendency (*vide supra*).

[1] See *Lancet*, 17th April 1886, p. 731, and 24th April 1886, p. 809.

CHAPTER XI

THE ADMINISTRATION OF CHLOROFORM

The reader is referred to Chap. I., p. 10, for a short account of the early use of this anæsthetic; to Chap. II., p. 25, for information upon its chemical and physical properties; to Chap. IV., p. 105, for a *résumé* of the chief experimental work that has been done concerning its physiological action; and to Chaps. V., VI., and VII. for remarks as to its safety and suitability in general surgical practice.

A. APPARATUS AND METHODS OF ADMINISTRATION

Section I.—The Administration of Chloroform Vapour with Atmospheric Air

Sir James Simpson, to whom we are indebted for the introduction of chloroform as an anæsthetic, first administered the drug by means of a simple handkerchief arranged in a cup-like form. An unmeasured quantity of chloroform, usually about a drachm, was poured into the hollow thus formed, and the handkerchief applied to the patient's face. He recommended that the vapour should be exhibited "powerfully and speedily," to use his own words,[1] and considered a gradual administration objectionable, owing to the frequent occurrence of inconvenient excitement. Subsequently he used a folded cloth or towel, and he continued to adopt this mode of administration for several years. In 1860, however, he again modified his procedure, apparently recognising the necessity of providing

[1] *The Works of Sir James Y. Simpson*, vol. ii., Edinburgh, 1871, p. 177.

for a more free admixture of air with the vapour. He therefore advised that a *single* layer of a towel or handkerchief should be laid over the patient's nose and mouth, and that the anæsthetic should be added drop by drop.

§ 1. Regulating or Percentage Methods of Administration

Snow was the first to draw attention to the fact that in order to obtain uniform results, and to avoid too concentrated a vapour, it was advisable to use some plan by which the proportions of chloroform vapour and air might be regulated. As already mentioned (p. 107), he made experiments with different percentages of vapour, and carefully recorded his results.

Snow's inhaler consisted of a double metal cylinder, the outer space containing water, and the inner one serving for the evaporation of chloroform from bibulous paper arranged in coils. The inner cylinder, which had holes at its upper part for the free admission of air, communicated by means of a flexible india-rubber tube with a face-piece containing inspiratory and expiratory valves. The inhaler was contrived to supply, at about 60° F., and in the ordinary process of inhalation, about 5 per cent of vapour; but it possessed an arrangement by which more air might be admitted if desired.

In 1849 Snow employed, in a few cases, a bag of known capacity, which could be inflated by bellows, and in this bag a measured quantity of chloroform was placed. He so regulated the proportions that an atmosphere containing 4 per cent of vapour resulted. He found this plan of administration, however, somewhat inconvenient, and preferred the inhaler just described.

Clover agreed with Snow as to the advantages of working with a known percentage of vapour, and for many years successfully administered chloroform upon these lines.

Clover's chloroform apparatus[1] consisted of a bag holding 8000 cubic inches of air, and connected by a flexible tube to a face-piece. The bag was charged before use by means of a bellows holding 1000 cubic inches. On its way from the bellows to the bag the air was made to pass through a warm chamber containing chloroform. Thirty to forty minims of chloroform were added to this chamber, by a graduated

[1] Described in Erichsen's *Science and Art of Surgery*, vol. i., 1877, p. 18.

syringe, for every thousand cubic inches of air pumped through. This would give from $3\frac{1}{2}$ to $4\frac{1}{2}$ per cent of chloroform vapour. The face-piece and tube of the apparatus were almost identical with those used by Snow.

Working upon the lines of Snow and Clover, Paul Bert subsequently came to the same conclusions as these observers, and administered, by means of special gasometers,[1] definite proportions of chloroform vapour and air. Bert's "méthode des mélanges titrés" has been already considered (p. 108). A number of operations were performed by M. Péan upon patients anæsthetised with the 8 : 100 mixture (= 8 gm. of chloroform : 100 lit. of air, or about one and a half per cent of chloroform vapour). It is stated that the excitement period was generally absent or but slightly developed; that there was no resistance on the part of the patients; and that deep and satisfactory anæsthesia was usually produced in seven minutes.

One of the most accurate instruments for delivering to the human subject chloroform atmospheres of definite strength is that known as **Dubois' apparatus**, already described (p. 108). This apparatus has the great merit of supplying weak and easily regulated chloroform atmospheres without imposing upon the patient the suction action which is inseparable from certain other instruments. The author has used Dubois' apparatus in several cases at St. George's Hospital in conjunction with Dr. Waller, and with satisfactory results. One patient, a potman, who had previously given trouble with the nitrous oxide-ether sequence, passed into anæsthesia with very little excitement; but the induction lasted 18 minutes, and there was some reflex movement with the first incision. Dubois' apparatus is costly, heavy, and complicated; whilst two persons are required to work it. Moreover, the induction period is usually inconveniently long with this as with other regulating chloroform instruments.

Waller's wick vaporiser has been already described (p. 111). Like Dubois' apparatus it can be used clinically, delivering to the patient definite chloroform atmospheres without imposing any respiratory exertion. The author has used this instrument at St. George's Hospital in conjunction with Dr. Waller, and it

[1] See Dastre, *op. cit.* p. 105.

seems to be quite as efficient as the Dubois apparatus, whilst it is much less complicated in its mechanism.

Within the last few years many attempts have been made to devise a portable chloroform inhaler capable of delivering dilute chloroform atmospheres of known strength ; and Mr. A. Vernon Harcourt has introduced the apparatus described below, which, in his opinion, fulfils these requirements.

The **Vernon Harcourt Inhaler.**[1]—The Harcourt inhaler provides, in sufficient quantity for full and free respiration, a mixture of air and chloroform which is automatically limited to a maximum strength of 2 per cent, and can be diluted at will with additional air down to any smaller proportion.

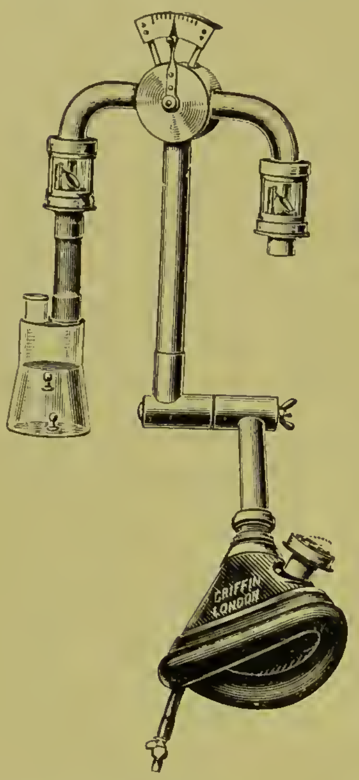


FIG. 45.—The Vernon Harcourt Inhaler.

The two-necked bottle is filled with chloroform to near the top of the conical part, and two coloured glass beads are dropped into the liquid to indicate when the temperature is within the range 13°–15° C. If the temperature of the chloroform is below 13° both the coloured beads will float : if it is above 15° both will sink : in the former case the proportion of chloroform inhaled will be less than the pointer of the stopcock indicates : in the latter case it will be greater. The proportion is also increased by any agitation of the bottle. During inhalation the chloroform is cooled by evaporation ; its temperature may be kept between 13° and 15° by now and then holding the bottle in the hand till the blue bead has sunk and the red bead is beginning to sink. The dimensions of the bottle have been arrived at after a great deal of experimental work and careful analysis. The diameter of the upper portion has been proportioned to the average rate of human respiration and to the rate of evaporation of chloroform between 13° and 15° C. To compensate for varying rates of respiration the inlet and outlet of the bottle are placed near together and at some distance from the surface of the liquid ; while to compensate for the lowering of the liquid surface by evaporation the vessel widens as the surface of the chloroform descends. The nearness of the two necks one to another, and the distance between them and the surface of the chloroform, diminish the variation in the proportion of inhaled air to chloroform vapour which is caused by

[1] This description is copied from the circular supplied by the makers of the apparatus, Messrs. J. J. Griffin & Sons, Ltd.

abnormally shallow or deep breathing. When the flow of air is gentle, much of it passes in at one neck and out at the other without reaching the surface of the chloroform or displacing wholly the mixture of air and chloroform which occupies the upper half of the bottle. On the other hand, the strong current caused by deep breathing drives out all the vapour which has been formed and promotes further evaporation by stirring the surface of the liquid. With bottles of the present dimensions this correction is only partial. If the rate of breathing is voluntarily reduced to 3 litres a minute instead of the normal 4 or 5 litres, or raised to 7 or 8 litres a minute, the proportion of chloroform may be raised to about 2·5, or lowered to about 1·5 per cent. It would not be difficult by lengthening the cylindrical part of the bottle to correct more completely for variations in the rate of breathing. But it is believed to be advantageous that the proportion of chloroform should vary thus, in order that there should be less variations in the total quantity of chloroform administered. Two ratios have to be considered in judging of the probable effect upon a patient, that of chloroform vapour to air, and that of the mass of chloroform inhaled to the mass of the body through which it is distributed.

The stopcock is so made, that when the pointer is at the end of the arc nearest the bottle of chloroform, the maximum quantity is being administered—namely, 2 per cent. When the pointer is at the opposite end, only air will be inhaled; and when it is midway, dilution of the 2 per cent mixture with an equal volume of air will make the proportion 1 per cent. The shorter lines on either side indicate intermediate quantities—namely, 0·8, 0·6, 0·4, 0·2; and towards the chloroform bottle, 1·2, 1·4, 1·6, 1·8.

The valves on the two branches prevent the entrance into the apparatus of expired air, and also serve to show whether the stopcock is working rightly. Only one valve opens when the pointer is at either end of the scale, both equally when the pointer is midway, and for all other positions one valve opens more and the other less, in the degree indicated by the position of the pointer on the scale. The movement of these valves shows also how full and regular the breathing is, and the slight click which they make conveys this information to the ears when the eyes are otherwise occupied.

It is generally found that beginning with the pointer at 0·2 and moving it on towards the chloroform bottle at the rate of one division about every half-minute up to 1·6 or 1·8 produces narcosis as quickly as is desirable.

For the maintenance of narcosis it is believed that 1 per cent or even less will be found sufficient. The stopcock can be moved by a touch of the finger so as at once to increase or diminish the dose.

If by fall of temperature or agitation of the bottle the yield of chloroform is diminished or increased, this may be allowed for at once by a movement of the stopcock.

The face-piece, which is provided with an expiratory valve, and can be fixed in any position, is either attached directly to the inhaler, which in this case is held in the hand and should be kept as nearly vertical and as steady as possible, or can be connected by about 20 inches of half-inch

rubber tubing; the inhaler in this case being supported on a stand or hung on to the back of the bed.

The mask is made of solid toughened rubber, fitted with a rubber air-cushion. It can be washed, or boiled, and as it becomes plastic in hot water the shape can easily be modified, if required, so as better to fit the patient's face.

Certain cases may occur in which a stronger dose is required than that afforded by the apparatus as above described. For increasing the strength of the vapour inhaled a small tube is provided which fits into the open neck of the bottle, raising the possible maximum dose to 2·5 or 3 per cent. To obtain a 2·5 per cent mixture the larger end of the tube, marked 2·5, must be inserted in the bottle, and for 3 per cent the smaller end, while the pointer is kept at the end of the scale nearest the chloroform. At intermediate positions of the pointer the dose will be increased in the same proportion as the maximum.

No chloroform evaporates excepting that which is inhaled by the patient; and only that which is exhaled passes into the air of the room. *A great economy of chloroform is thus effected, which should in a short time repay the cost of the apparatus to Institutions or medical men in large practice by whom it may be used.*

The apparatus must be carefully examined to see that the parts are adjusted, and the administrator should inhale or incline the instrument sideways to see that the valves are working properly. About 1½ oz. of chloroform should be poured into the conical bottle, and the beads introduced. The face mask should then be carefully applied. This is best done when the head is turned to one side. Breathing taking place freely and the air inlet valve and expiratory valve flapping properly, the inhaler should be grasped at the horizontal cross-piece with the right hand, while the lower jaw is pressed forward by the left hand placed behind the angle of the mandible. Firm pressure is necessary, as absolute co-adaption of the mask to the patient's face is essential. If the pressure used is equal over the whole area of the face, the patient will not complain. It is a common fault to allow air to enter by the sides of the bridge of the nose. Absolute fitting of the face-piece having been secured, the strength of the vapour may be gradually increased by turning the pointer. This is done slowly, but unless the patient is restless and struggles, not too slowly. Struggling is an indication for the lessening of the strength of the vapour, but not for removal of the face-piece, unless duskiness supervenes. When narcosis is attained, the usual signs being relied upon, in most cases the maintaining of anæsthesia can be effected with 1·5, 1 or even ·5 per cent, according to the physique of the patient and the requirements of the operation. After prolonged administration, slight duskiness may appear, and in this case the apparatus may be lifted for a few breaths and then replaced.

Mr. Vernon Harcourt's ingenious apparatus has now been in use for about two years. It has been extensively employed in several hospitals, and particularly in University

College Hospital. According to Dr. Dudley Buxton,[1] the inhaler produces very satisfactory results. In the hands of others, however, it has not fulfilled expectations. In the opinion of the writer its drawbacks are: (1) that the current through it depends upon the respiratory action of the patient; (2) that the face-piece pressure, which is often necessary in order to obtain proper chloroform percentages, may seriously interfere with free respiration; (3) that its management becomes irksome to the administrator, particularly in long cases; (4) that it cannot be used for many operations; and (5) that it cannot be readily sterilised. Reference has already been made (p. 113) to the disadvantages of making the respiratory pump of the patient also the pump of an apparatus. In the interesting case referred to on p. 362 the use of this inhaler probably had some share in bringing about the unfortunate result. Again, in the case referred to on p. 113 the respiratory arrest was almost certainly attributable to intercurrent asphyxia largely dependent upon the type of apparatus. The writer cannot too strongly dissent from the view that chloroform accidents are to be entirely prevented by regulating chloroform percentages. However perfect an apparatus may be in its mechanism—however accurately it may deliver this or that percentage of vapour, it cannot prevent that state of intercurrent asphyxia which is liable, in certain cases, to complicate anæsthesia. Such an apparatus may, in fact, have in itself certain inherent disadvantages which altogether outweigh its advantages as a regulating machine.

Other regulating inhalers have recently been introduced, amongst which may be mentioned that of Dr. **Levy**.[2]

Junker's inhaler was originally[3] intended by its inventor for the administration of "bichloride of methylene." The principle of the apparatus is simple. Air is pumped by means of a hand-bellows and

[1] See *Med. Press and Circular*, 23rd Mar. 1904.
[2] See *Lancet*, 27th May 1905, p. 1413.
[3] See *Med. Times and Gaz.*, 1867, vol. ii. p. 590; and 1860, vol. i. p. 171. Although Junker's apparatus when carefully used probably lessens the risk of chloroform narcosis, several deaths have occurred in connection with its employment. It is not a suitable inhaler for infants or young children, unless the chloroform be considerably diluted with alcohol or ether. For accounts of fatal cases see *Brit. Med. Journ.*, 29th Sept. 1888, p. 719; 15th Sept. 1888, p. 625; 21st Dec. 1889, p. 140; 31st July 1889, p. 88; 10th June 1882, p. 889; 24th Jan. 1903, p. 195; *Trans. Soc. Anæsthetists*, vol. vi. p. 57.

tubes through chloroform, and the air, carrying with it a varying quantity of vapour, is transmitted to a face-piece. In the original inhaler there was a vulcanite face-piece with an air-valve. In the models which are now made (Fig. 46), the face-piece is of flannel stretched over a wire-frame; there is a filling funnel introduced by Dr. Buxton, and a little stopcock between the bellows and the chloroform reservoir which converts the intermittent into a continuous air-current. Dr. Buxton and Mr. Hilliard have also devised foot-bellows. The bottle for the chloroform is graduated to hold from 1 to 8 drachms, and having been charged with somewhat less than the latter quantity, is suspended by a little hook from the coat of the administrator. The india-rubber tube leading from the bellows to the bottle may be termed the afferent or bellows-tube; that leading from the bottle to the face-piece the efferent

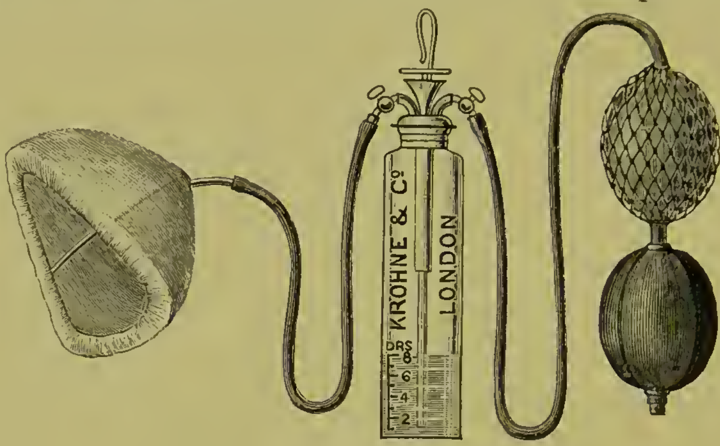


FIG. 46.—Junker's Inhaler.

or face-piece tube. Vulcanite and leather face-pieces, capable of closely adapting themselves to the face, should not be employed.

When it is desired to keep up chloroform anæsthesia without employing a face-piece, as in certain mouth and nose operations, the face-piece is disconnected, and a mouth-tube (Fig. 49) or nasal catheter is adapted to the efferent tube. When the hand-bellows is worked, air will be heard to bubble up through the chloroform. It is important, in using the inhaler, to see that the afferent and efferent tubes are attached to the right metal tubes of the bottle. It is also important not to have more than the proper quantity of chloroform in the bottle, otherwise some of the liquid may possibly gain access to the efferent tube. And lastly, care should be taken lest the bottle containing the chloroform become tilted during the administration.

It has, on more than one occasion, happened that, by an oversight, the india-rubber tubes have been adapted to the wrong metal tubes of the bottle containing the chloroform. The result has been that the liquid chloroform has been pumped into the face-piece, and in some cases into the nose or mouth of the patient.[1] A somewhat similar accident

[1] Death has resulted in more than one case. On one occasion tracheotomy became necessary in order to restore respiration after liquid chloroform had thus gained entrance to the upper air-passages.

has also been known to occur by the chloroform bottle becoming tilted during the administration. As one or two fatalities have arisen from these accidents the author thought it worth while to modify the inhaler, with the object of preventing the possibility of the tubes being wrongly adjusted, and rendering the bottle less likely to become tilted during use. Fig. 47 shows this modification. Air enters as usual through the hand-bellows. The afferent india-rubber tube is made much larger than that ordinarily used. The efferent tube is contained within the afferent, and emerges from the latter at right angles immediately above the hand-bellows. Arrows show the direction of the currents. The air entering the bellows passes along in the afferent tube system and bubbles up, as shown, through the chloroform. It then escapes by the efferent system. The stopcock shown in the figure controls both the afferent and efferent tubes. When it is turned off, the bottle may be placed horizontally, or packed away in a bag, without any of the chloroform leaving the bottle. The apparatus is conveniently worked as represented in Fig. 48. By this modification there is no possibility of the flexible tubes being interchanged ; and there is no likelihood of the bottle becoming tilted during the administration.

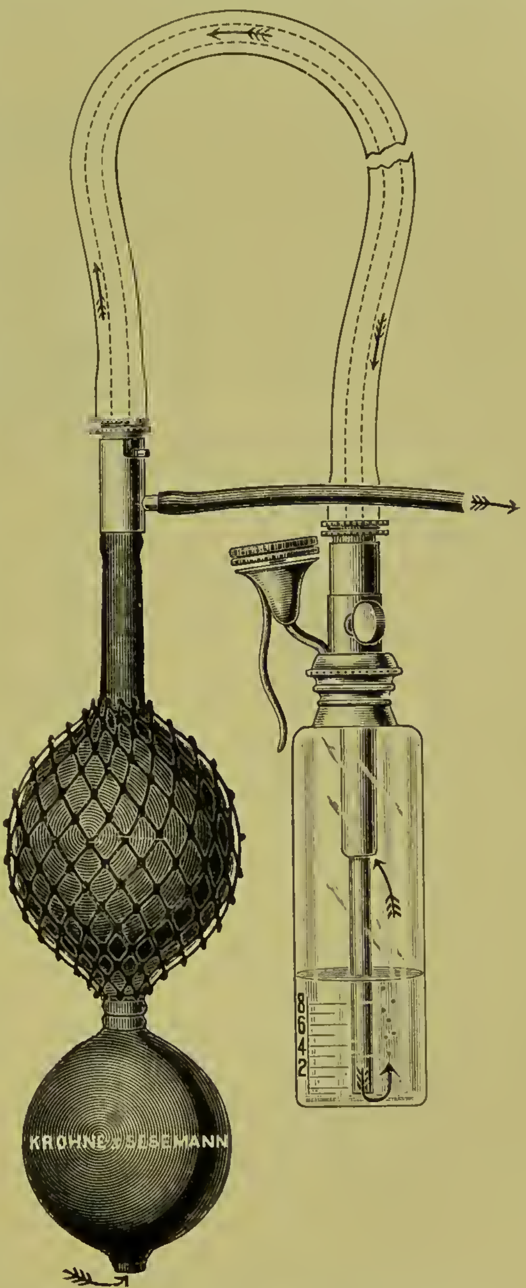


FIG. 47.—The author's Modification of Junker's Apparatus.

It is practically impossible to say what percentage of chloroform vapour is usually inhaled from the mask of Junker's apparatus. The percentage will depend upon a variety of circumstances. Foremost among these must be mentioned the quantity of air taken in with each inspiration. All kinds of breathing are met with during chloroformisation, from the deep regular respiration of the broad-chested and stalwart patient to the feeble and almost imperceptible breathing of the ill-developed and fragile child. Moreover,

respiration may vary in amplitude from time to time in the same patient, even though the same level of anæsthesia be maintained. The next most important factor is probably the manner in which the face-piece fits, or the degree to which air gains admission through it when it is

FIG. 48.—Showing the Modification of Junker's Apparatus in actual use.

adapted accurately to the features. Then we must take into account the temperature of the chloroform at the time ; and this will greatly depend upon the rapidity with which the air is forced through the liquid. Professor Zengerle of Constantz conducted, at Kappeler's request, some interesting experiments on this point.[1] His figures are here reproduced :

Experiment.	Compressions of Bellows per Minute.	Quantity of Air Supplied.	Chloroform evaporated.
1	120	4 litres	·7 gm.
2	60	2·2 ,,	1·2 ,,
3	40	1·6 ,,	1·4 ,,
4	30	1·2 ,,	1·5 ,,
5	24	1·0 ,,	1·6 ,,
6	20	·9 ,,	1·7 ,,
7	17	·8 ,,	1·7 ,,
8	15	·7 ,,	1·7 ,,

[1] Kappeler's *Anæsthetica*.

The temperature of the chloroform used was 63·5° F. From the experiments it is concluded that *the speed of pumping is in inverse ratio to the percentage of chloroform in the issuing air*—a point of some importance in practice. Lastly, the temperature of the room will also exert a slight influence.

Before using **Junker's inhaler** the administrator must see that it is in good working order. Having satisfied himself that it works properly, he should at first hold the face-piece at some little distance from the face, and gently compress the bellows. He will soon see whether his patient can breathe without discomfort the vapour he thus presents to him. The bellows should be compressed during the inspiratory phase of breathing. Gradually the face-piece may be brought closer to the face. By avoiding jerkiness in pumping, and by more or less rhythmically compressing the bellows, a tolerably constant chloroform atmosphere may be maintained. Rapid pumping, as pointed out above, is open to objection. When more chloroform seems indicated, the face-piece should be more continuously or more closely applied.

Junker's apparatus is very useful, one might almost say indispensable, in many operations within or about the mouth, nose, or pharynx. As already mentioned (p. 182), it is best in these operations first to secure deep ether anæsthesia, and then to continue with Junker's inhaler when the patient commences to emerge from the ether narcosis. Should the administrator decide upon this course, he must either give the chloroform vapour through the mouth by means of a metal tube (Fig. 49)

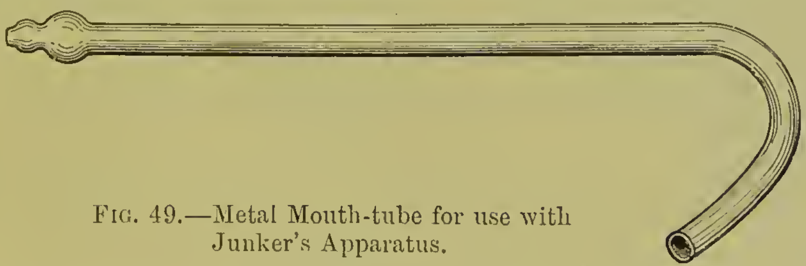


Fig. 49.—Metal Mouth-tube for use with Junker's Apparatus.

attached to the efferent rubber tube of the inhaler, or through the nose by means of a rubber catheter similarly attached. Whenever possible, the delivery of chloroform vapour is best effected by means of a nasal catheter, the end of which should be felt projecting just beyond the soft palate. When, however,

this course is impracticable, the mouth-tube must be used and one or both of the anterior nares temporarily plugged with sponge or lint in order to secure oral breathing. The most

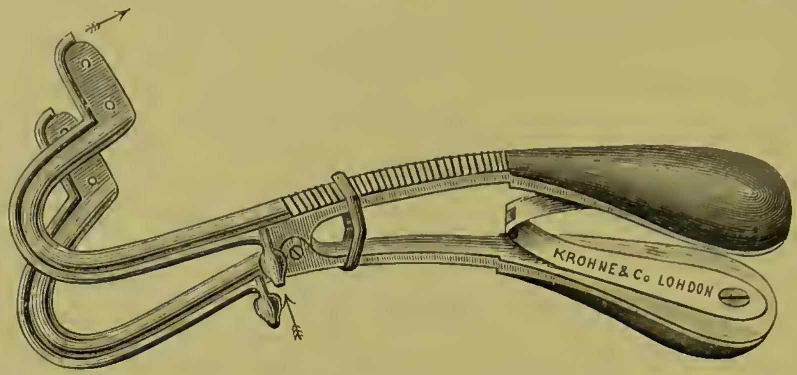


FIG. 50.—The author's Modification of Mason's Gag for use during operations within the Mouth and Nose.

frequent cause of "coming round" during intra-nasal or intra-oral operations is the delivery of chloroform vapour into the *oral* cavity whilst respiration is taking place through the *nasal*

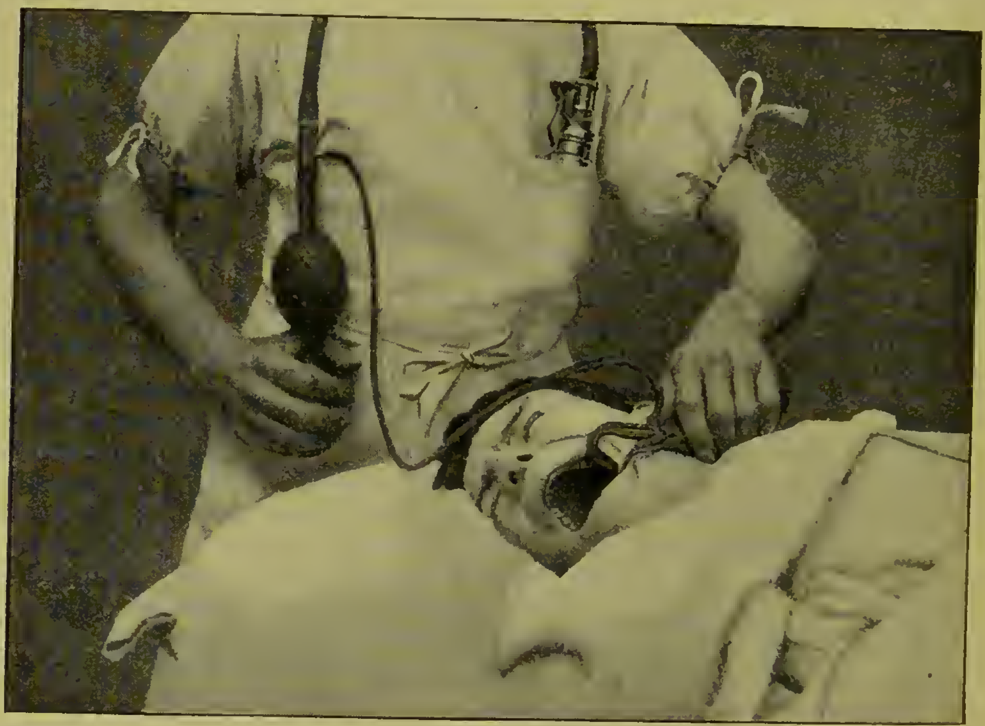


FIG. 51.—Gag of Fig. 50 in position.

channels. When the mouth is to be used for the introduction of the vapour, the appliance shown in Fig. 50 may be useful. It consists of a Mason's gag carrying metal tubes for the

transmission of chloroform vapour, the efferent tube of the Junker's inhaler being fitted to one of the metal tubes of the gag. This mode of anæsthetisation is shown in Fig. 51. In those cases in which the surgeon wishes the patient's head to be turned completely upon its side in order that he may operate upon the cheek or jaw thus rendered easily available, some difficulty in keeping a gag in position may be met with. It is obvious, in the first place, that some form of gag is necessary; and, in the second place, that the gag should be upon that side of the mouth which is lying against the pillow. A Mason's gag invariably becomes dislodged in these cases by reason of its handles resting upon the pillow. The author has found the gag of Fig. 52 to be useful on these occasions. It should be inserted between the canine or first bicuspid teeth on that side which is to lie upon the pillow. By rotating the wheel at the end, the mouth can be opened to any desired extent, and a mouth- or nose-tube used to keep up anæsthesia. In the removal of the upper jaw this arrangement answers well. Another plan is to insert one of the aluminium mouth-props shown in Fig. 19, p. 258, upon the side next the pillow; this arrangement answers well in antrum cases. When it is particularly necessary to avoid stretching the lips, the little appliance of Fig. 53 is very useful. It consists of a solid metal prop, of wedge-shaped form, to which is connected a mouth-tube for the transmission of chloroform vapour from a Junker's inhaler. The surfaces of the prop upon which the teeth rest are covered with lead. The orifice through which the chloroform vapour

FIG. 52.—The author's Screw-gag for use in certain nose and mouth operations.

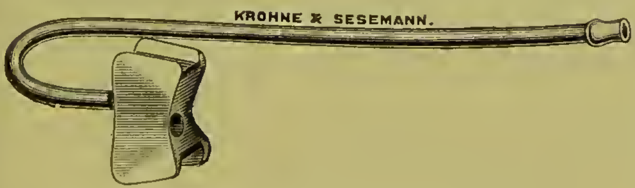


FIG. 53.—The author's Chloroform-prop.

enters the mouth looks backwards and inwards. Fig. 54 represents the chloroform-prop in position. The stretching

FIG. 54.—The Chloroform-prop in position.

of the lips in operations upon the antrum, and the pulling down of the anterior nasal openings in intra-nasal operations, are both avoided by this method of anæsthetising.

§ 2. Open Methods of Chloroformisation

We have already referred at the commencement of this chapter to Sir James Simpson's simple methods of chloroform administration. To such methods, and in fact to all those in which atmospheric air is allowed to freely mix in unknown proportions with the chloroform vapour, the term "open" is generally applied. It must be remembered, however, that this term is not always strictly appropriate; for it may happen, as when a cap, cone, or cup-shaped handkerchief is used, that the air supply to the patient is not as free as the word "open" would suggest. Ever since the days of Simpson there have been and still are advocates of

the simple or open as opposed to the complex or regulating methods of giving chloroform. Lord Lister in past years devoted much attention to the administration of chloroform by open methods. Writing in 1861 he recommended that a common towel, as suggested by Sir James Simpson, should be so folded as to make a square of six layers; that an unmeasured quantity of chloroform, sufficient to moisten a surface the size of the palm of the hand, should be poured upon the towel; that the latter should be brought as close to the nose and mouth of the patient as could be comfortably borne; and that more chloroform should be added from time to time. As Snow had drawn attention to the danger of too concentrated a chloroform vapour, and had from numerous experiments fixed the maximum proportion of chloroform vapour which should be inhaled at 5 per cent, Lord Lister was led to experimentally estimate the percentage of vapour given off from the under surface of a cloth moistened with $1\frac{1}{2}$ drachms of chloroform and placed immediately above the face. Snow had stated that as much as 9·5 per cent of vapour might be inhaled from a cloth at 70° F.; but Lord Lister's observations led him to state that the percentage of chloroform vapour breathed from a moistened cloth held close to the face was below 4·5 per cent, and therefore distinctly below the percentage employed by Dr. Snow in his inhaler. When we consider the numerous circumstances which may influence the percentage of vapour inhaled from a cloth moistened with chloroform, we cannot help receiving with some hesitation any statements made as to the percentage breathed in actual practice. This is indeed the weak point in the administration of chloroform from a folded towel. It is true that the risk of too concentrated a vapour may be greatly reduced by providing for the free access of air; but should this precaution be not continuously borne in mind, difficulties may arise. As Lord Lister has pointed out, a large surface moistened with chloroform, such as that which may be presented to the patient when employing a folded towel, handkerchief, or large piece of lint, will supply a much higher percentage of chloroform in the inspired air than a smaller surface. This consideration seems to have led him in

later years to use the corner of a towel drawn through a safety-pin, or otherwise constricted at a point a few inches from the corner itself, in preference to a folded towel or piece of lint. By using the corner of a towel in this way, a concave mask suitable to the size of the patient is formed, and the anæsthetic is added in small, but not too small, quantities at a time. In this way the greater part of the mask becomes saturated, and the moist condition is maintained till anæsthesia is produced. The little mask or cap should extend from the root of the nose to the point of the chin.

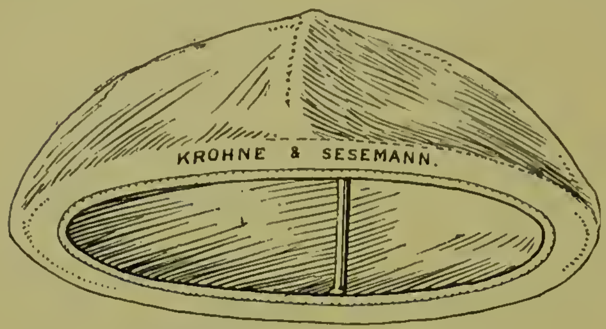


FIG. 55.—Skinner's Mask.

It differs in no material point from Skinner's or Esmarch's mask of open shape. From calculations which Lord Lister made, he estimated the volume percentage of chloroform inhaled to be about 1·2—a smaller percentage of vapour than that which he calculated was inhaled when he adopted the folded cloth for administering the anæsthetic.

FIG. 56.—The author's Drop-bottle.

Of all the open methods, that in which **Skinner's mask** (Fig. 55) and a **drop-bottle** (Fig. 56) are employed gives the best results. The particular mask shown is a slight modification of the original pattern. It is covered by a single layer of domett, and is collapsible. Its transverse wire arc, when adjusted as in the figure, keeps the domett well away from the face, so that blistering by the contact of liquid chloroform is prevented. The drop-bottle is one which the author devised some years ago, and which he finds to be very useful. The chief point about it is that the flow of chloroform can be regulated by the degree to

which the tap is turned. When the tap is fully turned on there is a small but continuous stream; when it is less open the stream is not quite continuous; when it is nearly closed chloroform can only be obtained by gently shaking the bottle. By this simple arrangement the administrator—who unconsciously acquires a habit of adding chloroform at certain intervals—can adjust the strength of vapour to the requirements of the case. In anæsthetising an alcoholic man, for example, it may be necessary to allow chloroform to freely moisten the mask; whilst in a susceptible subject a few drops at a time may suffice. In a series of densimetric observations Waller[1] has shown that Skinner's mask usually supplies to the patient an atmosphere containing from 1 to 2 per cent of chloroform vapour. In a similar investigation,[2] Mr. W. Legge-Symes has found that at ordinary room temperatures and with moderate quantities of chloroform, Skinner's mask yields vapour of fairly uniform concentration between the desirable limits of 1 and 2 per cent, the concentration reaching 3 and 4 per cent when the anæsthetic is copiously applied. Better results were obtained by dropping than by douching chloroform upon the mask. It was found that a fall in the frequency and depth of respiration might lead to the inhalation of dangerously concentrated vapour, even when the amount of chloroform was apparently not excessive. Open fabrics yielded higher percentages than close fabrics. Some kind of wire frame, such as that of a Skinner's mask, is greatly preferable to the corner of a towel, piece of lint, folded napkin, or other extemporised inhaler, for it is much more manageable, it delivers a more equable vapour, and is far less likely to allow liquid chloroform to redden or blister the skin.

Fig. 57 shows the Skinner's frame in use.[3] The patient should be requested to turn his head to one side, and to breathe quietly through the mouth. At first only a few drops

[1] *Lancet*, 9th July 1904, p. 80.

[2] "Note on the Concentration of Chloroform Vapour in Air drawn from beneath a Skinner's Mask."—*Lancet*, 9th July 1904, p. 81.

[3] The little bottle-rest shown in the figure is made by Messrs. Mayer and Meltzer. It consists of a flat piece of wood which can be inserted under the pillow, and the projecting end is furnished with a metal holder for the drop-bottle. The author has found this arrangement very useful in hospital practice.

of chloroform should be sprinkled upon the domett in order not to alarm the patient by any suffocative sensations. More of the anæsthetic may now be given, so that a distinctly moistened surface results. We have good evidence that the heroic plan of administration already discussed is not unattended by risk. But we must not lose sight of the fact that a too sparing use of chloroform is also open to objection. Any holding of breath or coughing may be met by a partial

FIG. 57.—Chloroformisation by means of Skinner's Mask.

withdrawal of the mask. The inhalation should not, however, be wholly discontinued. The ideal to be aimed at is to continuously give a well-diluted vapour. The administrator should steer between the two extremes, the rapid and the slow plans of administration. The author has found that by using the Skinner's mask and drop-bottle described, about $1\frac{1}{2}$ to 2 oz. of chloroform per hour is consumed by adult subjects, *i.e.* about 1 drachm every four or five minutes. Children and weakly patients require less than this; whilst in the case of alcoholic persons more will be needed. The average given is that for the first hour. Less will be required for the second,

and less again for the third, should the operation be of this duration.

§ 3. A comparison of the Various Methods of administering Chloroform Vapour with Atmospheric Air

At the present time (1906) there is, perhaps, no question in connection with the actual administration of anæsthetics which is more difficult to answer than that to which we must now direct our attention: Which is the best method of administering chloroform? At the moment of writing the whole subject of anæsthetisation by means of this agent is in an unsettled state, principally by reason of the recent introduction into practice of the several ingenious instruments above referred to, by which Snow's great principle, that of regulating the percentage composition of chloroform atmospheres, may be carried into effect. Whether this wave of ingenuity will leave any permanent mark behind it in the shape of one or more convenient appliances for the quantitative administration of chloroform, or whether, when it has passed, the simple and open methods of chloroformisation which have been for so long in use will again be almost universally employed, it is difficult or impossible to say. Not only does the question before us appear in different lights to different sections of the profession, but individual members of those sections will be found to hold different views according to the schools in which they have been educated, the appliances which they have personally studied, the exigencies of the particular line of practice in which they are engaged, and other circumstances. It is not surprising, therefore, that difficulty should be experienced in making any general pronouncement as to how chloroform should be administered. There is, however, a common platform upon which all those who are competent to discuss this question should meet—the safety of the patient. Whether we administer chloroform by the regulating or percentage system, or whether we give it by the open or drop-bottle system, our first aim should be the conservation of human life. This was the argument adduced when considering the selection of anæsthetics and

methods for routine use, and it applies with equal force in this connection. Given that chloroform has to be employed, the method which is adopted should be one which, in the hands of the particular administrator, is least likely to imperil the patient's safety, always provided, of course, that such a method is quite compatible with the surgical requirements of the case.

Let us first briefly consider the advantages and disadvantages of the regulating or percentage system of administering chloroform. Amongst the advantages claimed for the percentage system may be mentioned: the difficulty or impossibility of administering an overdose; the infrequency with which excitement and struggling occur; the even character of the anæsthesia; the rarity with which surgical shock takes place; and the lessened tendency to unpleasant after-effects. The disadvantages of the percentage system are chiefly connected with the apparatus which has to be employed. Percentage instruments often impede respiration by face-piece pressure (p. 113); they are only capable of being used in certain cases; they are often complex in construction, cumbersome in form, and liable to get out of order: their use involves a considerable waste of time during the induction period; the anæsthesia they produce is often inconveniently light in type;[1] they deliver, when shaken or moved, irregular percentages of vapour; they are by no means convenient when, as in hospital practice, the patients anæsthetised by their means have to be moved from the anæsthetising room to the theatre; they frequently occupy too large a share of the administrator's attention; they often become fouled by blood; and they are incapable of sterilisation. Moreover, as pointed out above, some of them depend for their chloroform intake upon the patient's own respiration—a state of things which is open to considerable objection in certain cases.[2]

[1] See, for example, *Clinical Journal*, 31st March 1898, p. 363.

[2] Of 101 chloroform fatalities collected by Kappeler, 9 occurred with complicated inhalers. Of these 9 deaths, 5 took place during the use of Clover's apparatus. Of the 109 fatalities collected by the English Chloroform Committee, 28 took place with inhalers, and in 5 of these 28 cases Snow's apparatus was being used.

The advantages of the open system of chloroformisation are: that by its use the administrator can easily keep the patient's air-way free from obstruction; that it is simple; that the mask and drop-bottle are exceedingly convenient and portable; that when once experience has been gained with these appliances it is possible to present to the patient dilute and more or less equable atmospheres of chloroform; that anæsthesia is quickly induced; and that the chloroform mask when soiled may be thoroughly cleansed and sterilised. The disadvantages of the system are: that unless the anæsthetist be experienced and watchful, irregularities in vapour percentage may favour the occurrence of excitement, struggling, embarrassed breathing, surgical shock, and overdosage.

Such being the respective advantages and disadvantages of the two systems of chloroformisation, let us next discuss what may be termed the personal factor in the administration of this anæsthetic. Medical students who, under the present schemes of instruction, are taught to administer chloroform, should certainly be taught methods which they will be able to apply in practice. To insist upon their invariably administering this anæsthetic by means of some comparatively complicated instrument which will, with rare exceptions, be unattainable in practice, is obviously unfair both to themselves as students and to the general public with whom they will subsequently have to deal. It is doubtless an excellent thing to allow all those who are receiving instruction to see in action and even to use chloroform inhalers capable of delivering definite percentages of vapour. By such means one of the great principles of chloroformisation—that of the continuous administration of a dilute and definite vapour—may be readily demonstrated. But as such students will almost certainly be called upon in after-life to administer chloroform under circumstances in which only the simplest methods of anæsthetisation will be applicable, and as there are in general surgery many cases in which, even though a regulating inhaler be at hand, chloroform can only be given by these simple methods, students certainly have a right to expect from their instructors tuition in open chloroformisation. House surgeons and other resident hospital officers who,

amongst their other duties, have to administer anæsthetics for general surgical operations, and who have presumably learnt the principles of chloroform-giving, employ, as a rule, the methods which are in vogue in the institutions with which they are associated. There is much to be said, however, for the adoption by such officers of methods by which it is difficult or impossible to administer an overdose of chloroform. Hospital work is often carried on at high pressure, whilst the surgeon in charge of a case not unfrequently prescribes the anæsthetic to be used. There is, therefore, special need for caution during this period in the educational career of a medical man, and the comparatively inexperienced house surgeon or house physician who is requested by the surgeon to give chloroform and chloroform only to all or certain of his patients, will probably be taking the wisest course in using a quantitative method. In the case of the practitioner who is only occasionally called upon to administer chloroform, and who has had no special experience in this department of practice, more satisfactory results will probably be obtained by the employment of some simple method with which he is familiar than by the use of a special inhaler with which he is unacquainted. Fortunately, cases are becoming less and less frequent in which comparatively inexperienced practitioners administer chloroform for general surgical operations. Let us finally consider the question of chloroform administration by those who have acquired considerable practice. All experienced anæsthetists know that by avoiding chloroform as an agent for *inducing* anæsthesia and by employing it only for *maintaining* anæsthesia its risks are so greatly reduced that there is little or no point in using a percentage inhaler. Were it necessary, in the cases requiring chloroform, to induce anæsthesia with this agent the position would be changed, and it might be imperative in the interests of the patient to invariably use percentage methods. But by the employment of one or other of the excellent induction methods at our disposal (Chap. XV. p. 497), and by continuing the administration by means of chloroform, the open system carefully applied fulfils all requirements. The greater the experience which has been acquired in the

simple or open methods the more equable will be the chloroform atmosphere presented to the patient; in other words, the more nearly will the administration approach to that which is possible with a regulating inhaler.

From the above considerations it is clear that there is no one method of chloroform-giving which is applicable under all circumstances. In addition to the numerous points to which reference has just been made there are others which may also influence the administrator in his choice of a method. Thus, in the surgery of the upper air-passages Junker's apparatus has become an almost indispensable instrument. Again, when portability is of vital importance, as in time of war, the simplest and lightest appliances for chloroform administration must be chosen.

Section II.—The Administration of Chloroform Vapour with Oxygen and Atmospheric Air

The system of administering mixtures of chloroform vapour and oxygen was introduced by Neudörfer of Vienna, who is stated to have excluded all air during his administrations.[1] Neudörfer's method has been modified by employing a Junker's inhaler, to the hand-bellows of which a bag containing oxygen is fixed, so that this gas instead of atmospheric air is pumped through the chloroform on its way to the face-piece. By this plan certain proportions of air are necessarily breathed with the oxygen.

For some time past an ingenious apparatus has been in use upon the Continent, and particularly in Paris, for the quantitative administration of chloroform vapour, oxygen, and air. It is known as the **Roth-Dräger-Guglielminetti apparatus.**[2] It consists of (1) an oxygen cylinder; to which is attached (2) an arrangement for reducing the oxygen pressure from 150 kgm. to ·5 kgm., and for registering the flow of the gas; (3) a contrivance by which so many drops of chloroform per

[1] See *Brit. Med. Journ.*, 25th January 1896; *Central. f. Chir.*, No. 35, 1887; *Central. f. klin. Med.*, No. 35, 1888; *Colonial Med. Journ.*, June 1896.

[2] See Dr. J. Lucas-Championnière's description in the *Journ. de Médecine et de Chirurgie*, 10th January 1905, p. 35.

minute may be added to the oxygen current; (4) a bag of gold-beater's skin for receiving the mixture of chloroform vapour and oxygen; and (5) an inhaling tube and face-piece, the latter being provided with an air-slot and valves, so that air may be breathed with the oxygen and chloroform vapour. During the induction stage, which generally takes about 8 or 10 minutes, chloroform is added to the oxygen stream at about the rate of 60 drops per minute for men and 50 drops per minute for women. For the subsequent maintenance of anæsthesia, 30, 25, or even 15 drops per minute will generally suffice. According to Dr. Championnière, the mixture that is usually breathed by the patient is one consisting of 2 parts of air and 1 part of chloroform-laden oxygen. Although there is no arrangement in the apparatus by which the chloroform percentage may be ascertained, this percentage is undoubtedly well within the limits of safety.[1] The advantages claimed for the apparatus are that by its use excitement is greatly reduced; that syncope never occurs; that patients retain their natural colour; and that recovery takes place quickly. By the kindness of Dr. Guglielminetti the author tried this apparatus at St. George's Hospital. Although an exceedingly interesting and ingenious instrument, it is, as will be gathered from the description, far too complicated for general use.

It is doubtful whether there is any great advantage in the addition of oxygen to atmospheric air during the administration of chloroform, save perhaps in cases in which much respiratory difficulty is present, and in these cases the use of any tightly-fitting inhaling apparatus would almost certainly neutralise the theoretical advantages of using oxygen. For patients who are so desperately ill that the administration of oxygen is considered advisable, it is probable that the simple arrangement figured on p. 341 will meet all requirements, the C.E. mixture being the anæsthetic employed.

[1] Dr. Waller and Mr. W. L. Symes (*Brit. Med. Journ.*, 24th December 1904, p. 1687).

B. THE EFFECTS PRODUCED BY THE ADMINISTRATION OF CHLOROFORM

First Degree or Stage.—When chloroform vapour is well diluted, *i.e.* when it is present in air to the extent of about ·5 per cent, the mixture has a sweetish taste and is pleasant to inhale. With a carefully adjusted and dilute vapour there are, as a rule, no objective phenomena during this stage. With concentrated chloroform atmospheres, however, breath-holding, cough, resistance, and other indications of unpleasant sensations will occur. The more dilute the vapour, the longer will this stage last.

Second Degree or Stage.—Incoherent talk, gesticulation and shouting are not uncommon in certain subjects. Muscular and alcoholic patients, as well as those who are hysterical and excitable, may give trouble, not only by struggling and attempting to rise into the sitting posture, but by the breathing becoming suspended. Muscular spasm of the jaws, neck, chest, and abdomen should be treated with great caution, air being freely allowed during and immediately after the embarrassed breathing incidental to such a spasm. Any clonic movements should be specially noted; they are generally of an asphyxial nature during this stage, and indicate a need for more air (p. 81). The frequency with which temporary respiratory embarrassment occurs in vigorous patients, particularly when chloroform vapour is administered to them in irregular percentages, probably explains the numerous fatalities which have occurred in such patients early in the administration. There is little doubt that when all the muscles of the body are contracted and the respiratory movements are, for the moment, suspended, the right heart is somewhat over-full; and air is needed in order to allow of that free pulmonary circulation which is essential for the escape of the imprisoned blood to the left cavities. The continuous inhalation of a dilute vapour will generally ensure an absence of most, if not all, of the excitement phenomena here mentioned. In those cases in which no suspension of breathing occurs, the natural respiration simply becomes somewhat

augmented, and in many subjects softly snoring, as the third degree of anæsthesia approaches.

It occasionally happens that, instead of respiration undergoing the usual changes above described, it becomes inaudible and almost imperceptible, although the patient is not fully anæsthetised. With this shallow breathing there is often slight pallor and some pulse depression, whilst the corneæ may be nearly or quite insensitive to touch. To this state, which has been termed "false anæsthesia," reference has already been made (pp. 72 and 154). Its true physiology is not thoroughly understood. It is most likely to appear when chloroform has been given sparingly and irregularly. It is least likely to manifest itself when some stimulus to respiration is in operation, as when an equable and properly adjusted vapour is being given, an apparatus involving increased respiratory work is being used, or some surgical procedure is in progress. There is a close connection between false anæsthesia and the act of vomiting; but what the precise connection is it is difficult to say. When, as frequently happens, this condition culminates in vomiting, the pallor and shallow breathing quickly disappear. It is not improbable that the chief factor in false anæsthesia is blood accumulation within the splanchnic area dependent partly upon vaso-motor effects produced by the anæsthetic and partly upon emotional disturbances before the administration. If this view be correct it is easy to explain the pallor, the lessened cerebral blood-supply, and the shallow breathing, and to see how a vicious circle may become established, the shallow breathing—originally caused by the abnormal accumulation of blood within the abdomen—favouring this accumulation by reason of lessened diaphragmatic movements. Whether the act of vomiting is in any way dependent upon an abnormal exudation of gastric fluids caused by this blood accumulation within the abdominal veins, it is difficult to say. The treatment of false chloroform anæsthesia is discussed on p. 518.

In some instances loud palatal stertor comes on early in the second stage, and should be disregarded, as it does not indicate the profound anæsthesia which it might suggest. In

others, the respiration is very deep and hurried throughout, but such cases are exceptional.

The state of the circulation will depend upon many circumstances. In most cases there is a tendency, as surgical anæsthesia approaches, for the initial acceleration of the pulse to gradually subside, and for a soft regular pulse of about the normal rate to become established. Any marked interference with free respiration, such as that which would arise from tonic spasm of the respiratory muscles during the period of excitement, reflex laryngeal closure, etc., will quickly modify the rate, regularity, and fulness of the pulse. The half-asphyxiated condition into which a patient passes when his air-way is intermittently occluded, or rendered temporarily useless for respiratory purposes in consequence of muscular spasm, rapidly tends to embarrass the heart's action during the inhalation of chloroform. Provided that all respiratory embarrassment be avoided and that the cornea be sensitive to touch, the circulation will remain perfectly satisfactory during this stage.

The pupils during this part of the administration are, as a general rule, mobile and more or less dilated. They react sluggishly, or possibly not at all, to light. As the third stage of anæsthesia approaches they usually show a marked tendency to become smaller and more fixed. The author finds, in notes taken by the late Dr. Sheppard, 53 cases in which the pupil was observed before full chloroform anæsthesia was established. In 26 it was "moderately dilated" or "dilated"; in 15 "moderately contracted"; and in 12 "contracted."

The ocular globes may, as the result of tonic or clonic spasm, move in this or that direction, or nystagmus may be present. According to Warner, the movements in this stage are always co-ordinate. Dastre states that somewhat later the globes may follow a light passed backwards and forwards before them.

Third Degree or Stage. — The **respiration** is usually regular, softly snoring, and somewhat quicker and deeper than normal.[1] Generally speaking, more of the anæsthetic will

[1] All varieties of respiration may be met with. The author has, for example, notes of a case in which, during deep anæsthesia for an abdominal section, the patient—a female aged forty-two, of average appearance—breathed at the rate of 62 per minute.

produce a louder stertor, and less will lead to quieter breathing. In some cases there is loud stertor, whilst in others the respiration, though satisfactorily performed, is almost or wholly inaudible. Plethoric, flabby, and stout subjects are more liable to stertor than others, and in these patients it may be necessary to push the jaw well forwards in order to maintain free respiration (see p. 529). A crowing laryngeal sound may accompany inspiration in some cases. This sound has already been discussed (p. 60). The presence of even a trace of corneal reflex indicates that the nervous mechanism of breathing is active, and that provided no obstruction exist respiration will proceed satisfactorily.

Much discussion has arisen concerning the **circulation** in deep chloroformisation. When the administration has been conducted in the proper manner, and temporary cardiac depression consequent upon too sparing a use of chloroform, or upon respiratory embarrassment, has been avoided, the administrator will find that the pulse becomes slower and steadier than it was during the first and second stages, and that it settles down to about the normal rate, or even less than this.[1] Dr. Leonard Hill finds that his "sphygmometer" indicates a rapid and persistent fall of blood-pressure to the extent of about $\frac{1}{3}$ or $\frac{1}{5}$ of the normal. As already indicated (p. 253), one of the commonest causes of pulse depression during surgical anæsthesia is surgical shock.

During deep chloroform anæsthesia the **eyeballs** are either fixed, or one may be fixed whilst the other slowly moves, or both may slowly move. The loss of associated movements was

[1] An abnormally slow pulse may point to an unnecessarily deep anæsthesia. The author has frequently found that when the pulse is very slow less of the anæsthetic will increase its rate. A normally slow pulse will still be slow during deep anæsthesia. The author has known a pulse of 46 per min. throughout the administration, the patient, a woman of 75 years, normally possessing a slow pulse. In 20 patients in whom Kappeler compared the pulse of deep chloroform anæsthesia with that observed a few hours before the administration when the patient was not excited, he found a diminution in rate of from 4 to 30 beats per min. Thus, in a child of 12, a pulse of 80 fell to 50; in a man of 60, a pulse of 60 fell to 52; and in a man of 56, a pulse of 72 fell to 48. The reader is referred to Kappeler's book for sphygmographic tracings of the pulse under chloroform. The Glasgow Anæsthetics Committee of the British Medical Association found that of 50 cases in which chloroform was given for surgical operations, 5 presented a pulse of 64, 7 of 60, 5 of 56, and 1 of 48 during deep anæsthesia (*Brit. Med. Journ.*, 18th Dec. 1880, p. 958).

pointed out by Dr. F. Warner[1] in 1877, and generally indicates a considerable and proper depth of narcosis. The author has, however, met with a case in which, even though the patient was deeply and properly anæsthetised, co-ordinated movements persisted. The eyeballs, if fixed, are usually in the horizontal plane.

The state of the **pupil** during the stage of surgical anæsthesia under chloroform has given rise to much comment, and is well worthy of careful study. Budin and Coyne were the first to direct particular attention to the pupil as a guide. All observers agree that it is usually contracted in deep chloroform anæsthesia, but the term "moderately contracted" seems to be more appropriate. By taking measurements with a pupillometer, the author finds that in most cases the pupil measures from 2 to 3 mm. in diameter, usually being about $2\frac{1}{2}$ mm. The average chloroform pupil is therefore decidedly smaller than the average ether pupil. The two resemble one another, however, in that they behave in a similar manner in response to an increase or decrease in the quantity of the anæsthetic given, and in that they are similarly affected by light and other stimuli. As will be pointed out below, the pupil is often of great service as a guide in chloroform administration. Occasionally it remains widely dilated throughout this stage, even though the anæsthetic has not been pushed too far. This is often the case during operations upon cervical glands. A very small pupil (1 or $1\frac{1}{2}$ mm.) in most cases indicates a light anæsthesia; whilst a somewhat dilated pupil ($3\frac{1}{2}$ to $4\frac{1}{2}$ mm.) usually means either that the anæsthesia is very profound, or more probably that the dilatation is of reflex origin, and is associated with a light anæsthesia. Very little reliance is to be placed upon the pupil as a guide until after the operation has been in progress some little while, and until the administrator has satisfied himself as to its behaviour with more and with less of the anæsthetic.[2]

It is generally taught that the **lid-reflex** should be absent;

[1] *Brit. Med. Journ.*, 10th March 1877, p. 292.

[2] For further information see an interesting article in the *Lancet*, vol. i., 1875, p. 550. Also a paper by Dr. H. J. Neilson, *Brit. Med. Journ.*, 20th July and 1st Oct. 1887.

but a very slight tendency towards lid closure when the cornea is touched with the finger may generally be allowed to manifest itself during surgical operations.

The **muscular phenomena** of deep chloroform anæsthesia are of interest particularly in relation to the onset of dangerous symptoms. Speaking generally we may say that as the third stage approaches, any muscular rigidity which may have been present during the second stage gradually subsides and general muscular relaxation takes place. Sometimes, however, certain parts of the muscular system remain rigid, or rigidity is reflexly provoked by surgical interference. Occasionally it is exceedingly difficult—indeed it may be unsafe—to abolish all reflex muscular spasm (p. 521). The most interesting of the muscular phenomena of the third stage of chloroform anæsthesia are certain clonic movements which may occasionally be observed early in that stage. These have already been referred to when discussing the muscular phenomena of anæsthesia in general (p. 80). Thus, there may be "piano-playing" movements of the fingers. Or there may be slow co-ordinated movements of the fingers, hands, and arms. Or, again, there may be jerky adductor movements of both upper extremities, the arms being spasmodically drawn to the sides at irregular intervals, apparently by spasm of the pectoral muscles. The last-mentioned arm movements may be associated with a widely dilated pupil and shallow breathing. It is probable that these clonic contractions of the pectoral muscles should be regarded as the result of impulses originating in the respiratory centre; the pectorals coming into action as extraordinary muscles of respiration. Owing, however, to the arms having become flaccid, the contraction of the pectoral muscles has no effect in increasing thoracic expansion. All that such contraction can do is to draw the arms towards the trunk. The jerky movements referred to are most conspicuous when the arms are hanging down on each side of the operating table. It is important to bear in mind that, if an operation be in progress when these clonic muscular phenomena are observed, the mistake may easily be committed of regarding them as indicating a return to the second degree of anæsthesia, and the administrator may continue the administration with the object

of securing greater quietude. Such a mistake may readily lead to grave consequences. Muscular phenomena of the type just described are generally referable to a somewhat inadequate air-supply. They should be taken to indicate a need for more air. Should they be associated with an insensitive cornea, the anæsthetic should be completely withdrawn till they have subsided.

The **colour of the face and lips** will depend upon the circumstances. As a general rule it is somewhat paler than normal. If the respiration be deep, quick, and unembarrassed there may be little or no alteration in the normal colour: if it be obstructed, a degree of duskiness, varying with the extent of the obstruction, the patient's natural colour, and the efficiency of the circulation at the moment of observation will result. There is less tendency to pallor in the Trendelenburg than in the horizontal posture. Should surgical shock arise, the colour of the face and lips will necessarily be modified.

Mucus and **saliva** are rarely secreted in sufficient quantities to attract attention.

The **bodily temperature**, according to Kappeler, who made many observations on this subject, is invariably reduced during the administration of chloroform. In thirty cases in which operations were performed the reduction varied from 0·02° C. to 1·1° C., the average being 0·59° C.

C. THE CHLOROFORMISATION OF INFANTS AND CHILDREN

The upper air-passages of these subjects are so sensitive that the administration of an anæsthetic, even though carefully conducted, generally causes the breath to be "held" both before and after unconsciousness. Should crying occur, a rapid intake of anæsthetic will ensue, and care must be exercised when employing chloroform to allow a very free admixture of air during this stage. It is a good plan, in fact, to withdraw the chloroform altogether directly the crying *begins* to show signs of abatement. If the administration be conducted without thus anticipating an excessive intake, an unnecessary, or even a dangerous, degree of anæsthesia may

ensue. Guthrie[1] points out that after the crying stage infants often pass into chloroform "sleep," with contracted pupils, convergent eyeballs, insensitive corneæ, and flaccid limbs. This false anæsthesia has been already alluded to (pp. 72, 154, 394). The peripheral circulation of infants is often difficult of appreciation under chloroform, especially if the extremities be normally cold. It is important, however, to keep a finger upon the radial pulse in all cases in which there is any doubt as to the depth of anæsthesia. The author has frequently found the circulation to be a valuable guide, especially in hare-lip and cleft-palate cases. In addition to the pulse quickly showing evidences of depression when too much chloroform is given, it also soon becomes feeble, or disappears, as the result of embarrassed or arrested breathing.

It is not a very difficult matter when the circumstances are favourable to anæsthetise infants and children during sleep.[2] The author has successfully accomplished this in several cases; but he has not always succeeded. A drop or two of chloroform should be placed upon a Skinner's mask held five or six inches from the child's face; a drop or two more should be added from time to time and the mask very gradually brought closer. In this way it is generally possible to so gradually increase the strength of the chloroform atmosphere that beyond an occasional act of swallowing, or possibly a little unconscious restlessness, the patient passes into deep chloroform anæsthesia without the slightest break separating the natural from the artificial sleep.

D. THE VARIOUS FACTORS WHICH MAY INDIVIDUALLY OR COLLECTIVELY LEAD TO DANGEROUS OR FATAL SYMPTOMS DURING CHLOROFORMISATION: POST-MORTEM APPEARANCES IN FATAL CASES

(a) *Introductory Remarks*

In preceding pages we have discussed what has been termed the experimental physiology of chloroform anæsthesia,

[1] *Clinical Journ.*, 7th April 1897, p. 377.

[2] See *Lancet*, vol. ii., 1872, pp. 514, 594. See also a letter from Dr. John G. Marshall in *Lancet*, 24th April 1886.

and have considered, in some detail, the effects produced upon the mammalian organism by toxic quantities of this anæsthetic. We have now to study the numerous clinical facts which may throw light upon the important problem of how and why chloroform accidents occur, and to see to what extent these facts harmonise with those to which attention has already been directed. At the first blush it might seem that we possess, in the vast number of physiological researches which have been conducted, a key to the correct interpretation and understanding of all the chloroform accidents in practice. This, however, is not so. If we wish to obtain a clear insight into the various modes of onset of dangerous or fatal symptoms during the use of chloroform in surgical practice, it is of paramount importance that we should bear in mind that, *in a considerable proportion of accidents, overdosage, in the usual sense of the term, is conspicuously absent.* It would, of course, be wrong to ignore the influence or to minimise the risks of the presence within the circulation of dangerous quantities of this anæsthetic. All the author would point out in this connection is that we have before us not merely the simple question of chloroform toxæmia, but other questions whose importance is equally as great or even greater.

The Committee appointed by the Royal Medical and Chirurgical Society in 1864, to inquire into the uses and effects of chloroform, collected and analysed 109 fatal cases which occurred in the years 1848-1863 inclusive. Kappeler, in his valuable work on anæsthetics, gives a similar analysis of 101 additional fatalities, which have been recorded in various journals as having taken place in the years 1865-1876 inclusive. As the matter is one of importance, and as Kappeler's work in this direction is not perhaps as widely known in this country as it deserves, it is proposed to present to the reader a combined analysis of the 210 cases.

An analysis of 210 chloroform fatalities (= 109 collected by the Committee of the Royal Medical and Chirurgical Society, and 101 collected by Kappeler).

(a) *Sex*

Males	150
Females	59
Not stated	1
	210

(b) *Age*

Under 5 years	2
6–15 years	21
16–30 ,,	49
31–45 ,,	53
46–60 ,,	37
Over 60 years	3
Not stated	45
	210

(c) *Nature of Operation*

Amputations	36
Dislocations	16
Removal of tumours	17
Examination of injuries (including putting up of fractures)	9
Operations on male genito-urinary organs	20
Operations on anus, rectum, etc.	11
Operations on female genital organs	5
Operations on eye	16
Hernia	3
Castration	4
For necrosis, excision of bone, etc.	7
Excision of joints	2
Forcible straightening of joints	7
For application of escharotics	8
Plastic operations	6
Ligature of arteries	1
Opening abscesses and sinuses	7
Impaction of fæces	1
For removal of teeth	18
Removal of toe-nail	5
For relief of neuralgia	2
For delirium tremens	2
For maniacal excitement	1
Not stated	6
	210

(d) *Period of Inhalation at which Death occurred*

Under 1 minute	10
1–3 minutes	13
3–5 "	12
6–15 "	33
Over 15 minutes	7
Not stated	135
	210

(e) *Stage of Anæsthesia at which Death occurred*

Commencing to inhale	14
Stage of excitement	30
Incomplete anæsthesia	49
Fully under influence	68
After operation	31
Not stated	18
	210

Or, Before full effects of chloroform	93
During full effects	68
After operation	31
Not stated	18
	210

(f) *Mode of Death*

It is best, perhaps, to keep the two analyses under this heading separate.

Royal Medical and Chirurgical Committee

Syncope	56
Syncope during stage of excitement	6
Died suddenly	6
Died in a fit	10
Pulse and respiration ceased together	9
Failure of respiration (pulse not noted)	6
Failure of respiration (pulse remaining)	2
Not stated	14
	109

Kappeler

Group 1. Imperfectly recorded cases, or cases in which death could not be ascribed directly to chloroform	61
Group 2. Fully reported cases in which death occurred as the immediate result of chloroform	40
	101

Analysis of Group 2

A. Death with primary evidences of circulatory failure (14 fully under and 9 partially under chloroform)	23
B. Cases in which respiration ceased first (10 fully under and 7 partially under chloroform)	17
	40

(g) *Mode of Inhalation*

On handkerchief, towel, napkin, or lint	87
Lint with sponge	5
On sponge	11
With an ether inhaler	2
Snow's inhaler	5
An inhaler	23
Paper bag or cloth cone	3
Skinner's mask	2
A mask	1
Esmarch's mask	5
Metal inhaler with plenty of air	2
Clover's apparatus	5
Not stated	59
	210

The above facts will act as a kind of clinical basis upon which to start our inquiry; and we shall have occasion to refer to certain of them in the following remarks.

It is well known that a large proportion of deaths during chloroform inhalation have taken place quite early in the administration before anæsthesia has become completely established. Of the 210 cases referred to, the period at which death occurred is stated in 75 cases only, *and in* 68 *of these* (*i.e. in* 90 *per cent*) *the patients died within the first fifteen minutes.* Comte[1] collected 232 deaths under chloroform. In 224 of these the time at which the fatal event occurred was mentioned; and of these 224 deaths, 112 (50 per cent) took place before anæsthesia was complete. The author finds 130 chloroform deaths reported in the *Lancet* and *British Medical Journal* from 1880 to 1889 inclusive; and of these, 54 took place either before the operation or during some short and trivial operation.

[1] Quoted by Julliard, *L'Éther, est-il préférable au Chloroforme?*

Before proceeding to consider the various factors which may individually or collectively lead to fatal symptoms under chloroform it is necessary that we should fully appreciate what happens in arrested breathing arising independently of the presence within the circulation of a toxic substance such as chloroform. Sudden spasm of the glottis, for example, will destroy life within a few minutes, the exact duration of the fatal phenomena varying with the special circumstances present. The arrested breathing leads to a stasis of the pulmonary circulation, to over-distension of the right heart, and finally to failure of this organ, partly from its inability to propel blood through the lungs, and partly from poisoning of its muscular substance by the non-oxygenated blood. In patients with a vigorous and normal circulation several minutes may elapse before cardiac action finally ceases; whilst in very feeble persons and in those with valvular or other cardiac affections the heart may fail almost immediately after cessation of breathing. We have seen in a preceding chapter that one of the most important physiological phenomena of chloroform inhalation is cardiac dilatation, and that this dilatation arises independently of all asphyxia; in other words, from the direct action of chloroform upon the heart muscle. Supposing, then, that before the full effects of chloroform have been produced, and whilst corneal reflex is still present, any intercurrent asphyxial state arises, not only do we have to reckon with pulmonary engorgement, secondary distension of the right heart, and the widespread effects of non-oxygenated blood, but we have an additional factor to deal with, viz. the continuous absorption of the incarcerated anæsthetic within the lungs and the action of this upon the already embarrassed cardiac muscle. It is hence very easy to see that in certain patients a very slight asphyxial strain under chloroform may cause sudden and fatal syncope, and that, even in the most vigorous subjects, death may take place within a minute or two of respiratory arrest.

(*b*) *The Possible Factors*

1. **The Factor of Susceptibility: Idiosyncrasy.**—The susceptibility of the particular patient to chloroform is a

matter of some importance in any inquiry concerning the supervention of dangerous symptoms. Billroth, Robert, and other competent authorities believe that, as with morphine, iodide of potassium, and other drugs, patients may display very marked susceptibility to chloroform, and may thus exhibit toxic symptoms from doses which, in the vast majority of cases, would have no such deleterious effects. This is quite in accordance with the author's own experience. In addition to the recognised differences which exist between alcoholic, neurotic, plethoric, and well-developed patients on the one hand, and temperate, placid, anæmic, and feebly developed persons on the other, one is often surprised by the very large or very small quantity of chloroform, as the case may be, which some particular patient requires; and, unless the administrator take the measure, so to speak, of each patient, he will be liable, when dealing with an extremely susceptible subject, to overstep the boundaries of safety. It is this consideration which seems to call for the use of some simple inhaler such as Skinner's, which is capable of supplying different strengths of vapour. The term "chloroform idiosyncrasy" has much to be said in its favour when applied to cases displaying this abnormal susceptibility.

2. **The Psychical Factor.**—Prior to the introduction of anæsthetics it was not an unknown event for death to take place from fright immediately before an operation;[1] and it is quite possible that in a few instances profound psychical disturbance has led to a fatal result during the first few inhalations of chloroform vapour, *i.e.* before the patient has become unconscious. But there is good reason to believe that the frequency of this so-called "fright-syncope" at the very outset of chloroformisation has been greatly exaggerated; for there are

[1] An interesting case is recorded by Kappeler (*Anæsthetica*, p. 118). The patient was a man, æt. 40; an amputation had to be performed. He was so feeble that chloroform was not considered advisable: a pretence was made to administer the agent by means of a cloth, but no chloroform was used. After four inspirations, respiration and circulation suddenly ceased: the man was dead. This case is interesting because it is in the highest degree probable that a similar result would have attended the use of chloroform, and that the death of the patient would have been attributed to the drug. Sir James Simpson refers to a somewhat similar case, in which a patient suddenly expired during the shaving of the groin, preparatory to an operation for hernia. Other instances of the kind might be quoted. See *Sir James Simpson's Works*, vol. ii. p. 144.

few, if any, accounts of similar accidents under nitrous oxide or ether. Admitting, for the sake of argument, that emotional states may, *per se*, prove fatal during the first two or three breaths of an anæsthetic, it is difficult to see why such fatalities should arise almost exclusively under the agent we are now considering. It is, in fact, in the highest degree probable that in many of the cases of supposed "death from fright under chloroform" the fatal symptoms have arisen during *unconsciousness*, and that influences far more potent than the mental disturbance itself have been at work. Errors as to the precise moment at which consciousness disappears under an anæsthetic are very common. The author has, for example, often heard the medical attendant of a patient address to the latter words of comfort or reassurance when to his certain knowledge consciousness has been in abeyance for several minutes, and the patient has been nearly or quite ready for the operation. It is, therefore, by no means improbable that in many of the recorded cases the patients have died whilst absolutely unconscious of their surroundings, *i.e.* in the second rather than in the first degree of anæsthetisation. We must not, however, lose sight of the possibility of psychical influences, originating during the conscious stage, prejudicially affecting the patient after consciousness has been destroyed. A complicated machine may be set going by a touch; but when once it has been started, it may be impossible to correct any faulty working which may manifest itself in time to prevent the machine coming to a standstill. So it may be with the half-anæsthetised subject. Emotional influences arising during consciousness may set in action certain respiratory and circulatory mechanisms which may still remain in operation even when all consciousness has been abolished; and these mechanisms may, under certain favourable conditions, bring about complete arrest of breathing, which, in the case of chloroform, may be rapidly followed by cardiac paralysis. It is a matter of everyday experience that highly nervous, emotional, and apprehensive subjects present peculiar and almost characteristic symptoms during and after the induction of anæsthesia; and so profound may be the initial modifications in respiration and circulation that the subsequent course of the anæsthesia may be altered. It would seem, indeed,

that acute mental disquietude, with its concomitant pallor or lividity, its feeble and quick pulse, and its restricted or excessive breathing, may introduce into the administration an element which may, especially in patients of certain physical types, lead to the development of dangerous or even fatal symptoms when all consciousness has been annulled by the anæsthetic. With nitrous oxide and with ether psychical disturbances are of practically no importance; but this is not so with chloroform. With the last-named anæsthetic, hampered and suspended breathing is, for reasons elsewhere considered, specially dangerous.

3. **The Factor of the Local Action of Chloroform Vapour.**—The question of the possibility of reflex cardiac inhibition taking place as the result of the contact of chloroform vapour with the mucous membrane of the air-passages has already been discussed (p. 126). Whilst many eminent physiologists are inclined to regard vapour concentration as likely to inhibit cardiac action, clinical observers are by no means agreed as to this explanation of certain early chloroform accidents. A strong chloroform vapour may doubtless induce "holding the breath," coughing, swallowing, and other symptoms; and it is quite conceivable that suspension of breathing thus arising may, in certain subjects, be dangerous (*vide infra*). It is highly probable, however, that the chances of accident from this source are very remote. A concentrated atmosphere is dangerous, not so much because of its power of reflexly arresting breathing, but because it may, if it reach the lungs, lead to toxic symptoms.

4. **The Factor of Intercurrent Asphyxia arising from other causes than the posture or the surgical procedure.**—When excitement and struggling are well marked, as they frequently are in alcoholic, nervous, or vigorous subjects, respiration may become embarrassed in the course of the general muscular contraction, and secondary syncope may arise. It is a significant fact that healthy and muscular patients are more liable than feeble subjects to display dangerous symptoms during the induction of chloroform anæsthesia. Children, old persons, and those patients who have become weakened by disease generally take chloroform

well. In the foregoing analysis of 210 fatal cases of chloroform inhalation it will be seen that one-half of the number occurred in patients between the ages of 16 and 45, *i.e.* during the most vigorous periods of life. As will also be seen, men are more prone to succumb under chloroform than women: about two-thirds of the patients were males. The better-developed muscular system of men is probably responsible for this difference. Other things being equal, the greater the vigour of the patient, the greater will be the tendency to the development of muscular spasm, not only of the extremities but also of the respiratory muscles, masseters, muscles of the floor of the mouth, larynx, and other parts. It is in this way that chloroform kills the perfectly healthy subject; the fatal symptoms commencing when the corneæ are sensitive, and the circulation failing before the anæsthetist can re-establish breathing. It was in this way that many of the fatalities recorded by Snow doubtless took place, although a totally different explanation of them was at the time advanced. The "spluttering at the mouth," lividity, and other indications of impaired respiration were, in fact, erroneously regarded as signs of primary heart-failure.

It is by no means uncommon for clonic muscular phenomena to arise during the second and third stages of chloroformisation, more particularly in cases in which the breathing is somewhat obstructed by stertor, jaw-spasm, laryngeal closure, etc. In some of the recorded cases of this kind patients are reported to have had a "fit," or to have been attacked by "epileptiform convulsions."[1] As already indicated, when discussing the muscular phenomena met with under chloroform (pp. 81 and 398) clonic contractions often indicate the approach of danger. The author has on three occasions known cessation of respiration to be preceded by these movements.

Spasmodic tongue retraction causing stertor and laryngeal spasm causing stridor may arise during chloroformisation and lead to dangerous symptoms (p. 529). Although usually dependent upon surgical stimuli, they may occur from other

[1] See Lord Lister's account of a chloroform fatality (*System of Surgery*, vol. iii., 3rd edition, p. 615). In this case the respiration ceased during an epileptiform spasm. A similar condition has been observed under ether (*Brit. Med. Journ.*, 2nd May 1885, p. 887).

causes. Lord Lister has drawn attention to the importance of recognising laryngeal obstruction under chloroform. He states[1] that a falling together or spasm of the arytæno-epiglottidean folds not unfrequently takes place, and that almost noiseless obstruction to respiration may thus result. He regards this condition as indicating a dangerous depth of narcosis; and there can be no doubt that when symptoms of laryngeal closure commence, they may often be relieved by giving less anæsthetic.[2] Some patients become dangerously stertorous in deep anæsthesia, whilst in others the presence of mucus, saliva, vomited matters, blood, etc., within the upper air-passages may introduce an asphyxial element into the administration.

5. **The Factor of Posture.**—This factor has been already fully considered (p. 237).

6. **The Factor of the Surgical Procedure.**—We have already studied in Chapter III. (pp. 73 and 75) the physiology of the reflex respiratory and reflex circulatory phenomena of anæsthesia; we have in the same chapter discussed the circumstances under which the three varieties of surgical shock—the respiratory, the circulatory, and the composite—may arise; and in Chapter VIII. (p. 250 *et seq.*) we have brought to a clinical focus the whole question of the influences of surgical procedures upon anæsthetised patients. Given that the power of appreciating pain has been destroyed by chloroform, whilst full anæsthesia has not yet been secured, the commencement or the continuance of a surgical procedure is far more likely to seriously disturb respiration than circulation—to bring about respiratory than circulatory shock. The time-honoured theory that dangerous or fatal *circulatory* shock is specially likely to take place from surgical interference during light chloroform anæsthesia must now be abandoned. Were reflex cardiac arrest readily produced by commencing operations

[1] *System of Surgery*, vol. iii., 3rd edition, p. 604.

[2] Snow does not seem to have recognised this particular danger, though he states (*op. cit.* p. 234) that, at a trial in France, M. Devergie urged that chloroform was capable of causing death by closure of the glottis. See also a pamphlet by Dr. Black, *Chloroform: How shall we ensure Safety in its Administration?* London, 1855. Dr. Black believed that all accidents under chloroform were due to closure of the glottis, but attributed this closure to the pungency of the vapour. More recently Ricord, Yvonneau, and Stanelli have dwelt upon the dangers of epiglottic and laryngeal obstruction under chloroform.

during light anæsthesia, deaths would be far more common than they are; for thousands of patients are annually operated upon whilst only partially anæsthetised by chloroform. That there is little or no risk from this quarter is shown by the fact that some surgeons habitually perform certain operations during light anæsthesia. It is, moreover, a matter of common observation that in very exhausted patients—the subjects who might be considered to be eminently liable to reflex cardiac arrest—it is safer to operate with a light than with a deep anæsthesia. When, however, full chloroform narcosis has been produced, surgical shock of a circulatory type is by no means uncommon, particularly during certain operations to which reference has been made, and it is this form of shock which is of special interest to the anæsthetist. It is of special interest partly because its symptoms, which are almost identical with those of true chloroform syncope, are frequently mistaken for the latter condition, and partly because its treatment, preventive and immediate, is largely in the hands of the anæsthetist. That many deaths have taken place from the commencement of operations before full chloroform anæsthesia has been produced there can be no doubt; but it is here contended that such deaths have come about from respiratory and not from circulatory shock. On the other hand, it is certain that in a considerable number of the cases in which alarming or even fatal symptoms have arisen during surgical operations upon patients deeply anæsthetised by chloroform, the surgical procedure in hand has been the immediate or exciting cause.

7. **The Factor of Vomiting.**—Incipient or actual vomiting during or immediately after chloroformisation may be attended by respiratory or circulatory depression which, under certain circumstances, may prove fatal.[1] The factor of vomiting would appear to admit of consideration from three different points of view. (i.) It has already been pointed out (p. 394) that pallor, feebleness of pulse, dilated pupils, and shallow breathing are not uncommon early in chloroformisation, particularly when this

[1] As an illustrative case see *Brit. Med. Journ.*, 21st July 1888, p. 135, and 14th June 1884, p. 1162. There is also a well-recorded example in the *Lancet*, 3rd March 1900, p. 632.

anæsthetic has been given sparingly, and that these phenomena, which are often erroneously ascribed to the toxic action of the anæsthetic, often indicate the approach of vomiting. In some cases, and particularly when undigested food is present in the stomach, very eccentric circulatory symptoms may occur. Whilst it is doubtful whether the circulatory disturbance here indicated ever culminates in fatal syncope without some other factor coming into play, it is in the highest degree probable that this disturbance has often paved the way, so to speak, for the lethal operation of some other factor, *e.g.* slight intercurrent asphyxia. (ii.) During the act of vomiting, laryngeal closure generally occurs, and suspension of breathing, sometimes of considerable duration, takes place. Whilst this suspension may be of little moment in a patient whose general condition is satisfactory, it may be hazardous in weakly subjects, and in those whose heart muscle is unable to withstand even a slight strain. The writer has on more than one occasion known the violent diaphragmatic contraction and the laryngeal closure incidental to vomiting to completely arrest the radial pulse of a patient suffering from moderate shock at the conclusion of a severe operation, the explanation doubtless being that which is advanced on p. 65. It is in the highest degree probable that in most of the cases in which fatal vomiting-syncope has been recorded, death has taken place from intercurrent respiratory interference prejudicially affecting cardiac action. (iii.) The entry of vomited fluids into the larynx and trachea is elsewhere discussed (p. 542).

8. **The Factor of Simple Chloroform Toxæmia: Fourth Degree or Stage in the Action of Chloroform.**—Simple chloroform toxæmia, that is to say, the condition produced simply and solely by the presence within the blood of dangerous quantities of chloroform, is probably less common in practice than is generally believed. It is here contended that in the majority of cases usually regarded as belonging to this group some obstruction to the free entry or exit of air is present. As already indicated (p. 41), simple chloroform overdosage is very easily obtained in the physiological laboratory, owing to the common practice in experimental work of introducing

chloroform vapour directly into the trachea. In man, however, this method of anæsthetisation is comparatively rare. When the air-passages are free, when there is no obstacle to the action of the respiratory pump, and when the percentage of chloroform in the air breathed by the patient is beyond the limits to which reference has already been made (p. 113) certain symptoms will make their appearance.[1] When studying the experimental physiology of this subject we saw (p. 116 *et seq.*) that the usual sequence of events in chloroform toxæmia was (1) progressive fall of blood-pressure; (2) paralytic failure of respiration; and (3) cessation of the heart's action. In practice it will be found that the symptoms of simple chloroform overdosage will depend upon the degree of vapour concentration, the rate and amplitude of respiration, and the state of the pulmonary blood stream. Should the administration have been conducted rapidly, recklessly, and without any attempt to limit vapour concentration, the patient may so suddenly die that all attempts to recognise the order in which the fatal symptoms have arisen may be completely futile. But when toxic quantities of chloroform are more gradually given, the symptoms displayed by the patient will be more capable of differentiation and analysis; although the period which elapses before such symptoms culminate in total cessation of respiration and peripheral circulation will still be very short. In most cases of overdosage complete corneal insensibility, dusky pallor, dilatation of pupils, separation of eyelids, feebleness, slowness, irregularity, or imperceptibility of pulse, and shallow breathing immediately precede respiratory arrest. As already pointed out (p. 116) cessation of breathing in chloroform toxæmia is largely dependent upon circulatory depression. As regards the pulse disappearance in simple chloroform overdosage it must be borne in mind that this phenomenon by no means necessarily implies cardiac arrest. In the great majority of cases the disappearance of the radial pulse simply indicates an extremely low blood-pressure. In those cases in which the symptoms of over-

[1] One of the best reported cases illustrating the mode of death from a concentrated chloroform atmosphere is to be found in the *Brit. Med. Journ.*, 25th October 1884, p. 811.

dosage come about comparatively gradually the indications of the colour, pupils, and pulse are of great value, for if they be observed in time, respiratory arrest may often be averted. Cardiac inhibition and vaso-motor paralysis from the direct effects of chloroform upon these centres are among the final phenomena of chloroform toxæmia.

Some observers have contended that chloroform is essentially a respiratory poison, and that the circulatory element in chloroform toxæmia should therefore be disregarded. As we have seen, however, respiration does not fail till the arterial pressure has greatly fallen. It is perfectly true that respiration generally, if not invariably, ceases before the heart muscle is finally paralysed, and that in chloroform administration attention should *primarily* be directed to the respiration, but the clinical fact remains that in all threatening or fatal conditions dependent upon simple chloroform toxæmia circulatory depression is the characteristic and dangerous symptom. Death usually takes place not from our inability to restore respiration but from our helplessness in reinstating cardiac action.

9. **Pathological Factors.**—The various pathological states which may favour or determine respiratory or circulatory arrest under chloroform are discussed in Chapter VI. (pp. 164 and 170).

10. **Conclusions.**—From the foregoing considerations four important deductions are permissible:—

(1) Dangerous or fatal symptoms during chloroformisation may take place during light or during deep chloroform anæsthesia, *i.e.* when the cornea is sensitive or when it is insensitive to touch.

(2) Simple chloroform toxæmia, *i.e.* the state produced by overdosage apart from any intercurrent respiratory or circulatory derangement, is comparatively rare in practice.

(3) Dangerous or fatal symptoms may arise from the operation of one or more of the factors to which reference has been made.

(4) Most of the factors referred to have this in common —they are capable of bringing about in the semi-anæsthetised or fully anæsthetised patient, a state of intercurrent respiratory embarrassment or asphyxia, the risks of which are greater

under chloroform than under other anæsthetics, and it is this intercurrent asphyxial state which is the key, so to speak, to the true nature and treatment of the great majority of the chloroform accidents of practice.

In the accidents that occur at the outset of chloroformisation, *i.e.* in association with a sensitive cornea, intercurrent asphyxia from muscular spasm usually plays an important part. Obstruction to the free ingress and egress of air converts a light into a deep anæsthesia, the latter condition becoming established partly by reason of the progressive absorption of incarcerated chloroform, partly by reason of anoxæmia, and partly by reason of retarded carbonic acid elimination. When a deep anæsthesia already exists, *i.e.* when the cornea has become insensitive, any intercurrent asphyxia will rapidly induce a state of syncope. This is sometimes well illustrated in practice when, during full narcosis, respiration becomes obstructed by blood or mucus. When threatening or fatal symptoms take place during certain operations, surgical shock of a circulatory type is often partly responsible for the symptoms.

When the circulatory system of the patient is in a satisfactory state, and the depth of anæsthesia is but light, the circulation will hold out for a comparatively long time against an asphyxial strain. When, however, the cardio-vascular system is in a state of degeneration, when the right cardiac cavities are already over-distended by reason of the presence of pulmonary or cardiac disease, or when severe circulatory shock is present, a comparatively slight degree of respiratory embarrassment, even though it arise during light anæsthesia, may rapidly prove fatal.

(c) *Post-Mortem Appearances*

It is a mistake to suppose that there is anything characteristic in the post-mortem appearances of patients who have died during chloroformisation; nor is it possible, as a general rule, to state precisely from these appearances what has been the particular mode of death in any given case. The conditions found post-mortem naturally vary considerably, according to

the stage of anæsthesia at which death has occurred, the presence or absence of intercurrent asphyxia, the state of the patient's heart and lungs prior to the administration, the nature of the remedial measures adopted, and other circumstances. Thus, in non-asphyxial cases in which the patient has died from an overdose of the drug gradually administered, the heart is usually found flaccid and empty, the lungs crepitant and not markedly engorged, and the brain not congested.[1] In deaths due largely to intercurrent asphyxia, general venous engorgement, distension of the right cavities of the heart, pulmonary congestion, and partial or complete emptiness of the left cardiac chambers will probably be met with. But when death results from some slight asphyxial complication in patients with feeble, fatty, or dilated hearts, there may be few if any of the ordinary evidences of asphyxia, owing to the right heart failing before any marked distension of its cavities has occurred. It is seldom possible to detect any odour of chloroform in the tissues. As regards the post-mortem appearances in animals killed by chloroform Snow states, as the result of several observations, that the right cavities of the heart were always found filled with blood, whether they died suddenly or gradually, the left cavities never containing more than a small quantity of this fluid. The Royal Medical and Chirurgical Committee also found in their experiments that, as a general rule, all cavities contained more than the normal quantity of blood, but that the right contained more than the left. In the majority of cases the lungs were of a bright florid colour, and in many instances there were sub-pleural ecchymoses. The liver, spleen, and portal system were, as a rule, congested, and the superficial brain vessels contained more blood than usual. MacWilliam[2] states that from experimental observations on animals it is impossible to say from the post-mortem condition of the heart whether death under chloroform has been due to primary cardiac failure or to asphyxia. In numerous animals killed by chloroform Schäfer and Scharlieb[3] found that the post-mortem appearances were

[1] For typical case see Snow, *op. cit.* p. 170.
[2] *Brit. Med. Journ.*, 5th April 1902.
[3] *Trans. Roy. Soc. of Edinburgh*, vol. xli. Part II. (No. 12).

similar to those caused by asphyxia from air-deprivation, even though artificial respiration by perflation had been performed during the introduction of the anæsthetic. In all the animals examined by these observers immediately after death, all the heart cavities (sometimes excepting the left auricle) were found distended with blood, the right auricle and great veins of the thorax being specially engorged. "The left ventricle always contained a considerable quantity of blood, but rather less than the right ventricle. If, however, the examinations were made some little time after death, the left ventricle was always found empty and firmly contracted." The pulmonary arteries were greatly distended with blood. Externally the lungs appeared healthy. In six out of twenty cases frothy bronchial mucus was noted. The abdominal viscera, and particularly the liver, were markedly congested. With regard to the amount of blood found within the lungs after death, Leonard Hill points out that much will depend upon whether respiratory arrest has taken place during inspiration or during expiration. He found that if the trachea were clamped at the height of a forcible expiration, there might be only $\frac{1}{60}$th of the weight of the blood of the body in the lungs; whereas, if the clamping were effected during a deep inspiration, there might be as much as $\frac{1}{10}$th. Kunkel [1] states that the heart killed by chloroform always stops in diastole, the contraction of the left ventricle, which has been so often reported, being simply a post-mortem appearance. Guthrie notes that Cooper, Binz, and Pritchard agree in their statements as to the blood after death under chloroform presenting a peculiar dark cherry colour, and being more fluid than usual. Fränkel [2] states that the kidneys, liver, and heart are found homogeneously altered and their specific elements affected by cloudy swelling (coagulation-necrosis), whilst deposits of pigment are met with in the renal tubules and in the hepatic parenchyma. Ajello [3] also describes degenerative changes in the liver, kidneys, heart, and blood-vessels in four cases of fatal chloroform syncope.

[1] *Handbuch der Toxikologie*, Part I., 1899, p. 449.
[2] *Virchow's Archiv*, 129 (1893), 2 Heft.
[3] *Annals of Surgery*, March 1897.

E. THE DEPTH OF ANÆSTHESIA NECESSARY FOR SURGICAL OPERATIONS

We can readily understand the discrepancies of opinion concerning the effects produced by chloroform when we reflect that administrators of large experience differ widely as to the degree of anæsthesia which they consider to be appropriate for surgical operations. One chloroformist will work with a light, another with a moderately deep, and another with a very deep anæsthesia. The success of Syme in administering chloroform appears to have been principally due to the almost invariable maintenance of a full narcosis. From what has been already said, the reader will have gathered that the surest way to avoid irregular and hampered breathing (which is liable to be followed by circulatory depression) is to work with that depth of anæsthesia in which such alterations in respiration are impossible. In the early days of chloroform, patients were rarely thoroughly narcotised. Struggling, tonic spasm, holding the breath, retching, vomiting, and other symptoms of imperfect anæsthesia were the rule rather than the exception. The patient was usually placed lightly under chloroform; the operation was quickly performed; and in many, if not in most cases, the anæsthetic was then discontinued. In those operations which could not be thus rapidly completed, the patient was allowed to become nearly conscious before more chloroform was given. Simpson, Syme, and Lister have, in their turn, drawn attention to the importance of a more free and uniform exhibition of this agent; and the profession is greatly indebted to these observers for their emphatic teaching. If chloroform is to be given at all, it must not be given too sparingly. The maintenance of full narcosis, however, reduces the workable area under chloroform to somewhat narrow limits. In other words, if we wish on the one hand to avoid the dangers of a light anæsthesia, and on the other those of an overdose, we must carefully study the phenomena of narcosis.

In order to maintain a proper level of anæsthesia the anæsthetist must be guided by—

(*a*) The respiration;
(*b*) The occurrence of swallowing movements;
(*c*) The lid-reflex;
(*d*) The state of the pupil;
(*e*) The strength and frequency of the pulse;
(*f*) The colour of the face and lips; and
(*g*) Rigidity of muscles in various parts of the body (hands, neck, etc.).

(*a*) When once a softly snoring form of **respiration** has been secured, an endeavour should be made to maintain it. The withdrawal of the anæsthetic will lead to tranquil and inaudible breathing; whilst an increased quantity of chloroform will, in most cases, favour the continuance of (or even augment) the existing snoring. Unfortunately it is sometimes impossible to obtain this desirable state of respiration; and the administrator may be in doubt as to the depth of the narcosis. Other guides, however, are usually available, and by the assistance of an act of deglutition, a smaller pupil, slight lid-reflex, an expiratory noise, or a tendency towards tonic muscular spasm, the administrator becomes aware that the tranquil respiration is indicative of too light an anæsthesia. The conversion of inaudible into audible breathing and the advantages of such a conversion are considered on p. 518. As a general rule we may say that—

Inaudible breathing,
A good colour and pulse,
A moderately contracted or contracted pupil, and
A slight degree of lid-reflex,

collectively indicate the need for more of the anæsthetic; and, as the result of increasing the quantity of chloroform, respiration will quickly become audible and deeper. If the patient has been allowed to come so far out of a deep anæsthesia that the inaudible breathing is associated with pallor, feeble pulse, and other indications of approaching vomiting, it may be difficult, or even impossible, to secure a deeper and noisier breathing till the vomiting has taken place.

As regards the shallow and somewhat hampered breathing of very deep chloroform narcosis, it may be said that this breathing, if carefully watched, is not fraught with any great

danger. It may indeed be necessary in certain cases, and in certain subjects, to proceed to this degree of narcosis in order to avoid reflex difficulties. The breathing in question is usually associated with the absence of lid-reflex, slight duskiness of the features, and a rather slow regular pulse, which, although not as full as in a less profound anæsthesia, is not markedly feeble. When the patient has passed into this condition the administrator will find that by briskly rubbing the face and lips [1] with a dry towel he can generally maintain efficient respiration.

High-pitched crowing breathing (inspiratory) is of considerable interest in connection with the administration of chloroform. Generally speaking, profound anæsthesia prevents its occurrence. In certain operations, however, it is practically impossible to obviate the laryngeal stridor, even by very large doses of chloroform. Should it tend to culminate in total cessation of breathing, the best plan is to suspend the anæsthetic and to proceed as recommended on p. 531.

The manner in which expiration is performed will often assist the administrator, and the author cannot do better than quote from Dr. Sheppard's notes, in which he finds the following interesting remarks:—

It would be useful and of practical importance to get at the exact series of signs connected with the expirations, as they are of great use in the conduct of many cases. They seem to occur pretty regularly in the following order, as the patient emerges from the deep regular breathing of chloroform narcosis. (1) Slight holding of the breath before the commencement of expiration, soon developing a definite catch. (2) The expiratory catch becoming definitely vocal, but only occurring at the commencement of expiration. (3) Definite expiratory phonation, the vocalisation continuing all through the expiration, or it may still retain the character of (2), and develop into straining. (4) Movements of tongue and lips, etc., producing inarticulate mumbling. (5) Definite articulate phonation.

---

[1] Mr. Meredith, of the Samaritan Hospital, informs the author that he used to find this little procedure of great value in the administration of chloroform for abdominal section. The late Dr. C. E. Sheppard also found it of advantage. In consequence of the recommendations of Mr. Meredith and Dr. Sheppard, the author has for years adopted brisk friction of the lips and cheeks when any tendency towards feeble respiration or circulation has arisen under chloroform; and always with good results. He has often been surprised at the immediate improvement. He has known almost imperceptible breathing to quickly become deeper and more audible, and has observed this change to be at once followed by a better pulse and colour.

Cheyne-Stokes breathing, of a more or less typical character, is not uncommon under chloroform, especially in exhausted and senile subjects. Although it is generally met with in profound anæsthesia, the author has known it arise when a slight conjunctival reflex was present. He has notes of one case in which it disappeared directly the A.C.E. mixture was substituted for chloroform.

(*b*) All that has been said with regard to the occurrence of **swallowing movements** under ether will apply in the present instance (p. 354).

(*c*) The **lid-reflex** is an exceedingly useful indication of the depth of anæsthesia. In order that its value as a guide may be fully appreciated, the remarks already made (p. 354) must be borne in mind. The chief point concerning this reflex under chloroform is that, after the commencement of the operation, a very slight degree of lid-closure in response to a gentle touch of the cornea may usually be permitted to manifest itself without the occurrence of the inconvenient accompaniments of light anæsthesia. Considerable experience, however, will be necessary before it is possible to work with such a fine adjustment in anæsthetisation. Old people, feeble subjects, and those who have lost much blood, or have became otherwise exhausted by the operation, may usually be allowed to exhibit distinct lid-reflex towards the close of an administration. On the other hand, there are certain cases in which both corneæ must be kept insensitive throughout, otherwise inconvenient phenomena, such as retching, coughing, and abdominal rigidity, may occur.

(*d*) The average chloroform **pupil** is smaller than the average ether pupil. It is a useful sign when others are equivocal; as, for example, when the breathing is shallow and the lid-reflex absent. Moreover, when from the nature of the operation the breathing is deprived of its usual characters, variations in the size of the pupil in response to more or less of the anæsthetic may be very significant.

The following extract from Dr. Sheppard's notes is worth quoting in this connection:—

The dilated pupil is an excellent guide as an indication of returning consciousness, but one must be *very certain* that the patient is recovering

and not actually becoming more deeply narcotised. . . . On administering a fresh dose, 5 to 10 minims, of chloroform to a child with the dilated pupil of recovery, the effect is *not immediate*, but after five or six inspirations after cessation of chloroform, the pupil becomes contracted. The postponed operation of chloroform is better seen in this way than in any other. Hence the danger of even 5 minims to a child with the dilated pupil of deep narcosis.

Speaking generally, a dilated pupil *plus* conjunctival reflex calls for more chloroform; whereas a dilated pupil *minus* conjunctival reflex should be taken to mean immediate withdrawal of the anæsthetic till the pupil has become smaller, or the conjunctiva slightly sensitive.

(*c*) Like the pupil, the pulse is of value as a corroborative guide. Some writers, and particularly those of the Scotch school, have laid so much stress upon the importance of *never* feeling the pulse that one is naturally tempted to inquire upon what grounds such teaching is based. It is contended (1) that the whole attention should be directed to the respiration; and (2) that, as the pulse may become feeble immediately prior to vomiting, the anæsthetist may be misled, and suspend the administration, instead of continuing it. It is perfectly true, and even self-evident, that if the administrator's powers of observation are so limited that he cannot trust himself to watch more than *one* sign, that sign should be the respiration. But let us hope that such anæsthetists are rare. It is certainly possible for an administrator of average ability to attend to many other indications than the breathing, without relaxing the almost automatic vigilance which he should obviously bestow upon that function. With reference to the pulse-feebleness, which often marks the approach of vomiting, there is surely no harm in knowing that such feebleness is present (although, as will be pointed out below, pulse indications are of little or no value so long as the cornea is sensitive), nor is there any objection to treating this feebleness, when it is obviously connected with light anæsthesia, by an increase of the anæsthetic. When corneal reflex has been destroyed, and deep anæsthesia produced, the slow, regular pulse of chloroform narcosis generally becomes established, and it is from this point onwards that the peripheral circulation will afford

valuable indications as to the depth of anæsthesia.[1] An exceedingly slow and feeble pulse will, for example, call for less chloroform; and this treatment will soon be followed by better circulation. In rare cases it is impossible to proceed beyond a certain point without inducing an intermittent action of the heart; and such cases must be similarly treated. The administrator should occasionally consult the temporal, facial, or superior coronary pulse.[2] If he can feel a fair pulse in either of the two former arteries, he may depend upon the wrist-pulse being better than he anticipates. The author has often been unable to distinguish a temporal pulse, although the radial was at the moment of fair volume. He finds that the superior coronary pulse is very accessible during chloroform administration.

One can quite understand the Scotch school and the Hyderabad Commission denying the value of pulse indications, for, according to their views, the administration should not be continued beyond the point at which corneal reflex disappears. The author fully admits that if a case can be conducted without destroying this reflex, and if breathing be unembarrassed and free, the pulse may be disregarded, except in cases of impending or actual surgical shock. But, as pointed out above, it is necessary in many cases to conduct the administration without allowing even a trace of lid-reflex to be present; and it is in such cases that the pulse gives valuable indications as to the depth of anæsthesia. The necessity for carefully observing the peripheral circulation in cases of surgical shock is sufficiently obvious.

(*f*) **The colour of the face and lips** is generally of value as a guide, although too much reliance must not be placed upon it *per se* (see p. 399). Thus the author has notes of cases in which the wrist-pulse has vanished (from surgical causes) without any marked alteration in colour; and it is a matter of everyday experience that a good peripheral circulation may coexist with pallor and lividity. A dusky or cyanotic aspect

[1] Snow (*op. cit.* p. 250) found that watching the pulse was of great service, especially when employing unknown strengths of chloroform vapour.

[2] The late Mr. J. Mills, who had a large experience in the administration of anæsthetics (*Lancet*, vol. ii., 1880, p. 912), also directed attention to the advantages of watching the pulse during the administration of chloroform, and quoted three cases in support of his view.

of the face is probably always indicative of deficient blood oxygenation and of the need of more air. Cyanosis in the *extremities* may, however, depend upon vascular stasis induced by surgical shock, and may coexist with a fairly florid complexion. Pallor occurring during a light anæsthesia generally means the approach of vomiting.

F. AFTER-EFFECTS

One of the great advantages of chloroform is that in the large majority of cases recovery from its influence takes place with comparatively little discomfort to the patient. Provided that attention has been paid to the points referred to on p. 226, that an even or satisfactory state of anæsthesia has been maintained, that no dangerous symptoms necessitating remedial measures have arisen, and that the administration has not been unduly prolonged, there will, as a rule, be few if any after-effects.

At the close of a chloroform administration patients generally pass into a heavy sleep without the supervention of **retching** or **vomiting.** Although the percentage of patients attacked by vomiting after chloroform is comparatively small, the vomiting which occurs is not uncommonly of a persistent and severe type.[1]

Hiccough is uncommon after chloroform. A case is recorded, however, by Dr. J. H. Donnell,[2] in which it lasted ten days, in spite of the most varied and assiduous treatment.

Pallor and pulselessness may occur during recovery, particularly in association with the act of vomiting. Provided that the pulse be satisfactory at the conclusion of the administration, and that the breathing remain unembarrassed, there is no special liability to circulatory depression after chloroform.

As **bronchial and pulmonary sequelæ** are far more frequently met with after ether than after chloroform, their incidence

[1] Snow and Clover reckoned that vomiting took place in 1 out of 7 chloroform administrations. They probably refer to severe cases only—not to transient vomiting. Mr. Rigden (see p. 357) found vomiting to occur in 32 per cent of his cases, and of these it was noted as troublesome in 16 per cent. Snow refers to a case in which vomiting after chloroform proved fatal; and others have occurred.

[2] *Lancet*, 2nd Dec. 1905, p. 1619.

has been specially considered in the preceding chapter (p. 539). The infrequency of these complications after chloroform is doubtless owing to the fact that mucus is rarely secreted in excessive quantities under this anæsthetic. Respiratory sequelæ may, however, occur when blood, vomited fluid, or septic matter has passed into the larynx, trachea, or bronchi during chloroform anæsthesia. It is in this way that septic pneumonia sometimes comes on after operations within or about the upper air-passages. Such sequelæ can hardly be fairly attributed to the action of the anæsthetic. Bronchial and pulmonary affections, more immediately due to the effects of chloroform vapour, may, however, occur in predisposed patients who have been subjected to prolonged anæsthetisation. Thus, the author has notes of a case in which an elderly gentleman, the subject of chronic bronchitis, died from acute bronchial catarrh after the administration of chloroform for upwards of an hour and a half for the operation of lithotrity. The respiratory sequelæ of ether-chloroform sequences are more frequently dependent upon the former than upon the latter anæsthetic.

Transitory **mental and muscular excitement**, similar to that referred to when dealing with the after-effects of ether, may occur in hysterical and neurotic subjects. **Delirium** lasting three days has been recorded.[1] **Loss of speech**[2] (attributed to cerebral hæmorrhage) has also supervened after chloroformisation. Persons who have had **maniacal attacks** before the administration of chloroform have been known to suffer from a recurrence of their mental disorder after the use of this anæsthetic.[3]

There is no good evidence that **renal complications** of any importance are liable to follow the use of chloroform unless, indeed, we regard the peculiar condition known as "acid intoxication" (p. 604) as dependent upon renal inadequacy. According to Sokoloff[4] and Ajello,[5] temporary **albuminuria**

[1] See a case (*Ether as an Anæsthetic*, by Josiah de Zouche, M.D., of Otago), in which delirium lasting three days, in a boy of fourteen, was met with after chloroform inhalation. It is quite conceivable that this may have been a case of what is now termed "acid intoxication."

[2] *Lancet*, vol. i., 1870, p. 553. Chloroform was given for tooth extraction. The aphasia lasted five weeks.

[3] See Savage, *Brit. Med. Journ.*, 3rd. Dec. 1887, p. 1199.

[4] *Wratsch*, St. Petersburg, No. 4, 1891.

[5] *Annals of Surgery*, March 1897.

is very common after the administration of this anæsthetic, and in patients with pre-existing albuminuria some increase in albumin may be produced. Thiem and Fischer[1] state that the urine may show traces of chloroform—the drug existing in an unchanged state—even twelve days after the administration.

Lastly, it would seem that the administration of chloroform may, under certain circumstances, be followed by so-called "**acid intoxication**" or "**aciduria.**" Reference has already been made in Chap. III. (p. 92) to the fact that certain **degenerative visceral changes** of a fatty character may, at all events in the lower animals, follow prolonged or repeated chloroformisation. According to many observers there is a close connection between these two conditions. This subject, however, will be fully discussed in the final chapter of the work (p. 604).

G. ILLUSTRATIVE CASES

The following cases will illustrate many of the points to which reference has been made in this chapter.

It may be well, in the first place, to cite a couple of normal cases.

Illustrative Case, No. 10.—F. æt. 19. Tall: well developed: has a flabby appearance, especially about lower part of face: full lips: no thoracic abnormality discoverable. Removal of caseous cervical glands. Administration lasted one hour. Skinner's inhaler. Breath held a little at first. No excitement or struggling. Respiration became gradually deeper and rougher. After 5-6 min. colour good, respiration regular and rough, pulse good and rather slow, pupils 3 mm., conjunctiva barely sensitive. Operation commenced. No reflex movement. Respiration continuing satisfactory, a slight lid-reflex was permitted, but when this reflex became at all marked more chloroform was given. Less chloroform caused the breathing to become quieter, the pupils smaller, and the lid-reflex more marked. More chloroform had exactly opposite effects. After stitches had been put in, and the anæsthetic withdrawn, the pupils enlarged, and the conjunctiva became very sensitive. In a second or two retching commenced, and a little mucus was ejected. Pupils then gradually became smaller.

[1] *Deutsche med. Zeitung.* Berlin, 2nd Dec. 1889. Also Dérémaux and Minet, *L'Écho Médical*, June 1904.

Illustrative Case, No. 11.—Florid, intelligent girl, æt. 16: average height, and slim build: pupils $4\frac{1}{2}$ mm. Removal of glands from neck. Administration lasted 46 min. Skinner's inhaler.

2.5	P.M.	Administration commenced.
2.9	,,	Muttering and swallowing.
2.11	,,	Pupils 4 mm.
2.12	,,	Ready for operation. Pupils $3\text{-}3\frac{1}{2}$ mm. Snoring, regular breathing. No movement with incision, but pupils went to 4 mm.
2.14	,,	Less stertor. More chloroform. Stertor more marked and pupils 5 mm. No lid-reflex. Very good colour and pulse.
2.16	,,	Pupils as before. Less chloroform seemed to make pupils, if anything, larger.
2.19	,,	Pupils still 5 mm.: doubtfully active to light. Florid colour.
2.20	,,	An act of deglutition. Pupils 4 mm. with lid-reflex. Increased quantity of chloroform now produces larger pupil.
2.23	,,	A slight cough. Pupils $4\frac{1}{2}$ mm. Increased the chloroform. Cough subdued. Slight crowing with inspiration. Chloroform again increased to subdue it. Pupils 5 mm. No lid-reflex. Pulse good and regular, about 75.
2.28	,,	Whilst glands were being removed from neighbourhood of carotid and jugular the respiration became shallow, and pulse a trifle less full. This shallow respiration lasted 2-3 mins. Lips briskly rubbed, with good results. Pupils $4\frac{1}{2}$ mm. No lid-reflex.
2.32	,,	Respiration stertorous and deeper again. Good pulse: doubtful lid-reflex.
2.35	,,	Pupils $3\frac{1}{2}$ mm. No lid-reflex. A little moaning with expiration, and less stertor. Chloroform increased, with result of deeper stertor and larger pupil. (Obvious influence of more chloroform in causing a larger pupil.)
2.36	,,	Slight cough and crowing breathing. Anæsthetic increased.
2.38	,,	Pulse very good.
2.41	,,	Pupils 4 mm. Doubtful lid-reflex. Administration continued. Pupils $4\frac{1}{2}$ mm.
2.42	,,	Quieter respiration. Slight expiratory moan suggestive of impending cough, and pupils became $3\frac{1}{2}$ mm. Stitches now put in, and pupils at once dilated to 5 mm.
2.51	,,	Administration discontinued.

In the following case, which is taken from Dr. Sheppard's notes, aortic and mitral disease were present.

Illustrative Case, No. 12.—F. æt. 35. Aortic and mitral disease. Ovariotomy. Worked almost entirely by the pupil, and phonation occurring during expiration. The following was the sequence :—

(*a*) { Contracted pupil, Conjunctival reflex present, Expiratory phonation :

Then (*b*) { Pupil gradually dilated, Conjunctival reflex abolished, Slight expiratory phonation :

Then (*c*) { Dilated and fixed pupil, and Cessation of phonation.

About m.xv. of chloroform took the patient through all these stages; and the recovery back to contracted pupil took, roughly, a minute or so. Laryngeal musical stertor present all through, and not much affected by position of head or pulling jaw forwards. Pulse good all through, and patient came well and quickly out of the narcosis.

The administration of chloroform to a patient suffering from dyspnœa due to an enlarged thyroid is exemplified in the following case. As the dyspnœa did not increase under the anæsthetic, but actually diminished, it was probably the outcome of laryngeal spasm rather than of pressure upon the trachea.

Illustrative Case, No. 13.—M. æt. 17. Tall: slim: full lips: rather nervous. Occasional distress in breathing. Prefers to be propped up somewhat. Dry sounds throughout both lungs. Occasional moist cough. Audible stridor on taking a deep breath. Large thyroid growth. Operation 10 A.M.: dry, bright, cold morning. Chloroform on lint. Administration, 1 hour 13 minutes; operation, 1 hour 5 minutes. Two oz. of chloroform used. Head and shoulders slightly raised. Anæsthetic cautiously given. Barely audible breathing became audible (both inspiration and expiration). Thought it best, as breathing seemed to be getting rather laboured, not to push anæsthetic. Long incision. Very slight reflex movement, and deeper breathing. Occasional swallowing. Rather free hæmorrhage. Breathing grew quieter, *although no part of growth yet removed.* Thyroid now removed. Pulse got slightly feeble during extraction of left lobe, which was deeply seated; it then improved. Conjunctival reflex often present, with large (5 mm.) pupil; more chloroform abolished reflex and made pupil smaller (3 or 2½ mm.). Pupils hence good guide. Face rather pale. No movement throughout. During removal of left lobe, transient inspiratory stridor of high pitch, but no cyanosis. No flattening of trachea discovered.

The following case seems to indicate that the presence or absence of the lid-reflex may be dependent upon the nature of the operation in progress (see p. 72).

Illustrative Case, No. 14.—F. æt. about 50. Febrile. Spare build. Heart-sounds and chest expansion good. Exploration and evacuation of a tubercular kidney. Skinner's mask. Administration lasted 1 hour 20 minutes. An abdominal incision was first made, and subsequently a lumbar opening. After about one hour the patient's condition was as follows, the operator working at the lumbar opening:—Pupils contracted: lid-reflex either completely absent or only present in the slightest degree: pulse good, regular, about 72: respiration quiet. The operator now passed in sponges through the abdominal wound, with the *immediate* result that the breathing became deep, the colour more florid, and so much lid-reflex appeared that the lids tightly contracted when the conjunctiva was touched. We might say that this patient was, at the moment referred to, sufficiently anæsthetised for the lumbar operation, but not for the abdominal. The interest of the case, however, lies in the reappearance of the lid-reflex as the direct result of a particular stimulus, namely, interference with the peritoneum. See p. 73.

CHAPTER XII

THE ADMINISTRATION OF ETHYL CHLORIDE

THE reader is referred to Chap. I., p. 11, for a short account of the early use of this anæsthetic; to Chap. II., p. 34, for information as to its chemical and physical properties; to Chap. IV., p. 134, for a brief epitome of the somewhat scanty experimental work which has been done concerning its action; to Chap. VI. for the indications, so far as the state of the patient is concerned, for its employment in practice; and to Chap. VII. for a description of the particular surgical procedures which may be appropriately performed under its influence.

It will be convenient in the present chapter to consider the administration of ethyl chloride *per se.*[1] The use of mixtures containing this anæsthetic will be discussed in Chap. XIV.; and of sequences with ethyl chloride as one of the anæsthetics in Chap. XV.

Ethyl chloride resembles nitrous oxide in the rapidity with which it abolishes consciousness; it is similar to ether in that its effects are seen to their best advantage when moderate air-limitation is practised during its administration; and it is like chloroform in the suddenness with which it may kill when administered in an overdose. The problem before the anæsthetist is to use the drug in such a way that its advantages are secured whilst its disadvantages are avoided. Like other anæsthetics it has its special place or position in the field of modern surgery, and it is a mistake to attempt to obtain with

[1] For much interesting and valuable information concerning ethyl chloride the author is indebted to the writings of his friend Dr. W. J. McCardie, Anæsthetist to the General, Dental, and Ear and Throat Hospitals, Birmingham. See *Lancet*, 4th April 1903, p. 952; and *Lancet*, 7th Oct. 1905, p. 1023.

it results which can only be properly obtained with other agents. At the moment of writing (May 1906) our knowledge of ethyl chloride anæsthesia is very imperfect; but it is nevertheless necessary to attempt to place before the reader all that is at present known concerning its practical side. Unless ethyl chloride be gradually discarded, it is probable that in the near future the methods now in use for securing narcosis by its means will undergo considerable improvements, and that many of the uncertainties with which the use of this anæsthetic is at present surrounded will disappear.

From Koenig's experiments (p. 134), and from the clinical observations made by the author (p. 432) it would seem that, as with other anæsthetics, the effects produced by ethyl chloride primarily depend upon its vapour tension in the atmosphere presented to the patient. But the last-named observations tend to show that there is no definite percentage mixture the continuous inhalation of which will produce satisfactory results. With percentage mixtures sufficiently weak to be respirable without discomfort, an unsatisfactory type of anæsthesia results; whilst with mixtures sufficiently concentrated to produce narcosis satisfactorily, the initial sensations are so unpleasant as to proscribe such initial vapour concentration. So far as our present knowledge goes it would seem that, with this anæsthetic, the best results are to be obtained by a rational and cautious use of the close system of anæsthetisation (p. 47), the vapour being gradually but increasingly added to the to-and-fro respiratory current till anæsthesia takes place. We have yet to ascertain whether any special concentration of vapour should be aimed at, after consciousness has been destroyed, and if so, how such concentration may best be secured. We have also to determine by future research the relative influences of the oxygen limitation and the carbonic acid retention which are involved in close methods of administering ethyl chloride.

A. APPARATUS AND METHODS OF ADMINISTRATION

Experience has shown that if ethyl chloride be administered to adults from an open or semi-open inhaler, *e.g.* from a

Skinner's or Rendle's mask, so that a low vapour percentage results, large quantities of the drug will be needed to bring about even partial anæsthesia. In many cases indeed an excited state is produced, and the third degree of anæsthetisation is not attained. On the other hand, children may usually be satisfactorily anæsthetised by Rendle's inhaler although, even in their case, a close method, carefully applied, is usually preferable.

In the course of a clinical investigation conducted by the author at St. George's Hospital a few years ago[1] ethyl chloride was administered by numerous methods.

It was found that when **percentage mixtures** of its vapour and air, of sufficient strength to produce anæsthesia, were administered by the valvular system (p. 46), *i.e.* without re-breathing, swallowing movements and inconvenient apnœic pauses in respiration occurred, and that the results were unsatisfactory so far as the type of anæsthesia was concerned. The mixtures thus administered contained 9·3, 11·9, and 12 per cent of ethyl chloride vapour respectively. With this system of anæsthetisation suffocative sensations were sometimes experienced at the commencement of inhalation. Definite quantities of certain percentage mixtures of ethyl chloride vapour and air were next administered in such a way that (1) about one-half of the quantity taken was breathed by the valvular system when (2) the remainder was breathed by the close system. The percentages used in this method were 9·8 and 14·1. The results, however, were not satisfactory. In the next series of cases (1) a definite ethyl chloride and air mixture diluted with a further unknown quantity of air was breathed by the valvular system; (2) the pure mixture, of known composition, was then breathed by the same system; and finally (3) the remainder of the mixture was breathed by the close system. The mixtures employed contained 10·5, 10·7, 13·9 and 24·4 per cent respectively. Again the results were unsatisfactory, swallowing and shallow breathing characterising the administrations. It was clear from the results obtained up to this point that the continuous inhalation, without re-breathing, of mixtures of ethyl chloride and atmospheric air produced effects of an inconvenient type. A measured quantity (5 c.c.) of the drug was next administered by means of a Clover's ether inhaler, to which was attached a bag containing 10,000 c.c. of air, the expirations being at first allowed to escape but being retained during the second half of the administration. By this plan it was possible to increase the strength of vapour so gradually that there was little or no discomfort to the patient, and a better general result followed. Thirteen administrations were next conducted by the simple plan of (1) placing 3000 c.c. of atmospheric air in a bag; (2) allowing the patient to commence re-breathing this air: and

[1] For a full account of this investigation see *Lancet*, 19th Nov. 1904, p. 1408.

(3) gradually diffusing therein a measured amount of ethyl chloride contained in a small glass tube connected with the bottom of the bag. The results were now very satisfactory. The shallow breathing, apnœic pauses, and unpleasant after-effects which had characterised the uniform percentage cases failed to manifest themselves, and a good type of anæsthesia was produced. In 9 of these cases 5 c.c. of ethyl chloride were used; in one case 4 c.c.; and in 3 cases 3 c.c. It is difficult or impossible to say what percentages of ethyl chloride vapour actually reached the lungs in each of these administrations. Taking one of the 5 c.c. caees and assuming, for the sake of argument, the room temperature to have been 18·8° C.[1] and the administration to have been conducted slightly differently, *i.e.* in such a way that the *whole* of the ethyl chloride was vaporised before the mixture was admitted to the patient's air-passages, the percentage of the mixture entering the naso-oral cavities during the first inspiration would have been about 35·5, this percentage falling with each subsequent inspiration by reason of the increasing dilution of the bag-contents with the gases originally present in the air-passages. But under the conditions which obtained the percentage composition of the earlier inspirations was obviously far below 35·5 owing to the ethyl chloride having been *gradually* added to the to-and-fro current. As regards the percentage composition of the later inspirations this would, as in the hypothetical case just considered, be also considerably below 35·5 owing to a similar and progressive dilution of the bag contents. Even if we knew the percentages of ethyl chloride actually reaching the lungs in methods of this kind we should still have to reckon with other factors—the progressive using up of oxygen and the retention of carbonic acid (p. 47) within the closed circuit. As regards the particular method of anæsthetisation now under discussion it is only right to add to what has already been said, that although it produced very good results in the 13 cases referred to, it was subsequently found to answer somewhat less satisfactorily than methods in which the patients' own expired air, as opposed to fresh air, was used to partially fill the inhaling bag prior to the introduction of the anæsthetic.

With the foregoing considerations to guide us it would seem that the **apparatus required for the administration of ethyl chloride for brief operations** such as those of dental or throat surgery should consist of (1) a graduated bulb or other contrivance by which the administrator may know the exact quantity of the drug he is employing; (2) an accurately fitting face-piece connected by wide bore channels with (3) a rubber bag, preferably of stout rubber, and sufficiently capacious to receive at least three or four full expirations of a well-developed adult patient; and (4) some simple arrangement

[1] The day was warm, but no record was made of the actual room temperature in this batch of administrations.

or mechanism by which the ethyl chloride vapour may be so gradually admitted to the to-and-fro respiratory current that no distress in breathing or resistance results. Many of the inhalers now in use have their internal channels encroached upon by otherwise ingenious mechanisms for introducing the anæsthetic; others are intended to hold lint, absorbent cotton, or sponge, and are open to the great objection that when in use the medium for the absorption of the anæsthetic itself greatly interferes with free respiration; whilst others are provided with bags which by reason of their small size are quite unsuitable.

Fig. 58.—Graduated glass tube for administering ethyl chloride.

The author has found the small **glass tube** here figured of great use in administering ethyl chloride. The requisite dose is introduced into this tube from the glass spray-bulb in which the anæsthetic is obtained from the makers, and by attaching the little tube to the lower part of a rubber bag provided with a small stopcock the ethyl chloride may be so gradually added to the bag that no discomfort to the patient results. As the vapour of this anæsthetic is heavy and tends to remain at the bottom of the bag, it more gradually diffuses into the to-and-fro current than when the ethyl chloride is introduced, as is so often the case, between the face-piece and bag.

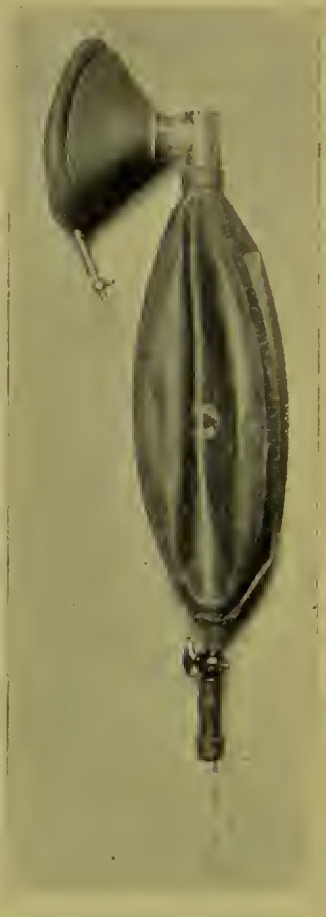


Fig. 59.—Face-piece and bag of Clover's inhaler, with glass tube of Fig. 58, arranged for administering ethyl chloride.

One of the simplest and best forms of apparatus for the administration of ethyl chloride is here depicted (Fig. 59).

It consists of the face-piece and bag of a Clover's ether inhaler of the type shown in Fig. 35, p. 330, the bag being fitted below with a small vulcanite stopcock for the attachment to it of the little glass tube of Fig. 58. If the wide-bore ether inhaler of Fig. 41, p. 334, be used, it will be necessary to interpose between the face-piece and the bag a metal collar (supplied by the makers of the inhaler) for connecting these two together.

In **conducting the administration** with the foregoing apparatus, the glass tube is first charged with from 2 to 5 c.c. of ethyl chloride according to the type of patient: it is then attached to the vulcanite stopcock of the bag, the stopcock being closed: a small mouth-prop is inserted between the teeth in order to retain command of the air-way should masseteric spasm occur: the face-piece is then applied, and is pressed more firmly during expiration than during inspiration, so that the bag becomes nearly filled with expired air: the vulcanite tap is then opened: the glass tube is gradually tilted so that its contents enter the bag: and the administration is continued till the signs of ethyl chloride anæsthesia appear. If these few simple directions be followed there will be little or no discomfort when the ethyl chloride vapour enters the respiratory current, although it is difficult on all occasions to completely eliminate the pungency of the vapour. Attention must carefully be paid to the avoidance of undue air-deprivation.

The apparatus shown in Fig. 60 was originally devised by the writer for the C.E. mixture. It was found, however, that by a very simple addition it could be made to act vicariously and quite efficiently as an ethyl chloride inhaler. The apparatus does not pretend to any special advantages over the simpler inhaler just described, or over any other ethyl chloride inhaler constructed on proper principles. It is merely introduced here because those who may find it of use for the C.E. mixture may also be glad to avail themselves of its convenience for ethyl chloride.

It consists of a wide-bore face-piece fitting into a wide-bore metal tube carrying at right angles a metal cylinder furnished at one end with a wide open chimney, to which can be attached a rubber bag (Fig. 60). The face-piece and bag of the wide-bore ether inhaler of Fig. 41, p. 334, also fit the metal cylinder of this inhaler. Fitting tightly within that half of the cylinder which carries the chimney there is an inner cylinder

capable of a limited range of movement by raising or depressing the little handle shown in the figure. The outer cylinder has a slot cut in its circumference to allow of the handle passing to and moving the inner cylinder, and the latter has two circular holes in its circumference, one for the passage of inspired and expired air and the other for receiving a small glass graduated tube of ethyl chloride.

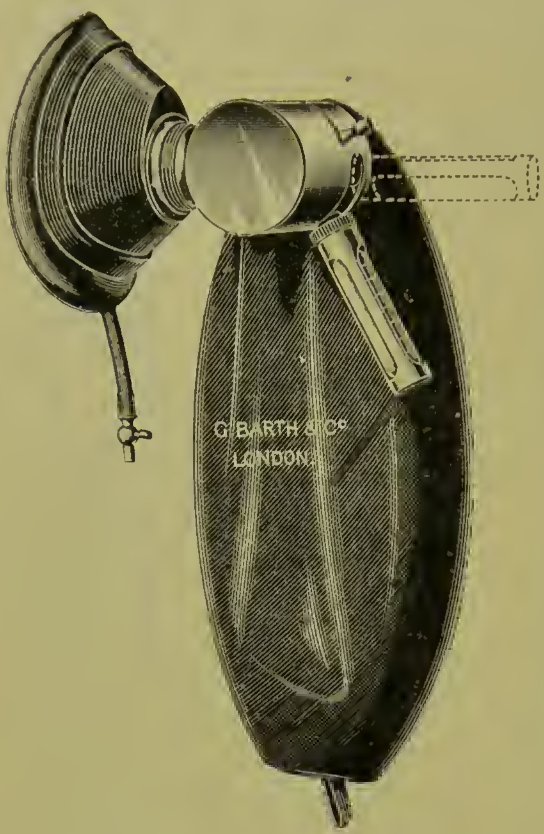


FIG. 60.—The author's C.E. inhaler adjusted for the administration of ethyl chloride. (See also Fig. 62, p. 463.)

The **administration is thus conducted.** The glass tube charged with the appropriate quantity of ethyl chloride is plugged into the lower hole of the inner cylinder; and the apparatus with its bag attached is applied as above described. As the air-hole is not a large one, respiration takes place only partly through it, a certain degree of re-breathing occurring into and out of the bag. By applying the face-piece rather more firmly during expiration than during inspiration the bag gradually becomes filled. Owing to the angle at which the ethyl chloride tube is placed the anæsthetic does not at present enter the vaporising cylinder. The administrator now very gradually rotates the inner cylinder, either by means of its handle or by raising the ethyl chloride tube now plugged into the inner cylinder (Fig. 61). This gradually closes the air-hole, and exclusively to-and-fro breathing results. As in the preceding method, air-limitation must be cautiously practised. If more ethyl chloride be needed, it may be introduced through the face-piece into the vaporising cylinder.

The **Ormsby inhaler** of Fig. 43, p. 338, without its sponge, also answers very well for the administration of ethyl chloride. The requisite amount of the drug is sprayed or poured into

the bag; the face-piece, with its air-valve fully open, is applied as already described; the air-valve is gradually closed; and anæsthesia becomes rapidly induced. If preferred, the dose of ethyl chloride may be introduced into the bag of the inhaler in a glass bulb, to be broken by the administrator at the commencement of the inhalation. As in other close methods, air must not be too rigorously excluded.

Clover's ether inhaler, and particularly its modification,

FIG. 61.—The administration of ethyl chloride by means of the author's C.E. inhaler.

figured on p. 334, may also be used for ethyl chloride. In warm weather the metal reservoir should be cooled by cold water or by vaporising a few c.c. of ethyl chloride in its interior before the administration commences. From 3 to 5 c.c. of the anæsthetic are then placed in the reservoir: the indicator is turned to "0": the bag is filled by a few expirations: to-and-fro breathing is commenced: the indicator is gradually turned to "1," and then more rapidly to "2," "3," etc., according to the special circumstances present. The remarks already made on air exclusion must be borne in mind.

McCardie prefers Clover's inhaler to any other for this anæsthetic, owing to the ease with which the anæsthesia from ethyl chloride may be supplemented by that of ether, should occasion arise.

B. DOSAGE

The reader is referred to the general remarks on dosage on p. 49. The quantity of ethyl chloride required to produce anæsthesia will depend upon the type of subject, the extent to which air is permitted to dilute the vapour, and the system of anæsthetisation adopted. A comparatively small quantity of the drug will produce a powerful effect if the air-restriction and re-breathing factors be freely employed. Given that the method be a close one, and that the re-breathing be judiciously practised, 1 or 2 c.c. of ethyl chloride will suffice for children, 3 or 4 c.c. for average adults, according to their physique (p. 161), and 4 or 5 c.c. for strong men, alcoholics, excessive smokers, and those who are known to be insusceptible to anæsthetics.

C. EFFECTS PRODUCED: SIGNS OF ANÆSTHESIA

We have seen (pp. 432 and 433) that neither the open nor the valvular system of administering ethyl chloride produces good results. We shall therefore deal exclusively in this section with the effects produced by close methods, such as those just enumerated, and we shall limit our remarks to the effects of single administrations for short operations. The prolongation of ethyl chloride anæsthesia for more protracted cases is discussed in the following section.

When the administration has been conducted, according to the principles to which reference has been made (p. 433), the effects produced by ethyl chloride generally come about with remarkable rapidity. Consciousness is lost in a few seconds, and, as a rule, without any noticeable discomfort or resistance. If the vapour be not gradually admitted some breath-holding and unpleasant sensations will necessarily result. Sometimes there is a stage of excitement with or without muscular rigidity. Muscular men, those who are addicted to the

excessive use of alcohol or tobacco, and excitable and nervous patients may give some trouble during this stage. As a general rule, however, respiration grows deeper, quicker, and more regular, stertor becomes increasingly audible, the features assume a flushed appearance, the globes become fixed, the pupils dilate, and the conjunctivæ, or even the corneæ, lose their sensibility to touch. Temporary respiratory embarrassment, from spasm of jaw and other muscles, is not uncommon in muscular and other subjects predisposed to this condition, and may lead to some cyanosis. Speaking generally, it may be said that when the breathing has become distinctly stertorous, the administration should either be discontinued or a breath of air admitted. Writing recently[1] McCardie states that he finds it advisable to admit a breath or two of air rather earlier than this, *i.e.* when the patient's breathing has become regular, and this course he regards as important, especially in bad subjects. Ethyl chloride resembles other anæsthetics in that the respiratory phenomena which it produces will, if carefully observed, be the best guide as to the need for air. If the drug has brought about a profound effect, *e.g.* if it has led to deep, rapid breathing with stertor, to deep breathing and muscular relaxation, or to dilatation of pupils and insensitive cornea, there can be no question as to the advisability or even the necessity of admitting air or suspending the administration. In some cases muscular relaxation accompanies stertor, but there is more often some rigidity. In certain subjects rigidity may be so general as to culminate in opisthotonos. McCardie states that during narcosis the pulse is usually rather slower than normal, and that Malherbe and Roubinovitch, using Potain's sphygmo-manometer, found that in man the arterial pressure almost invariably fell. A rash somewhat similar to that of ether may sometimes manifest itself. Micturition, or even defæcation, may occur.

As is the case with other anæsthetics, the **rapidity** with which the signs of ethyl chloride anæsthesia come about will depend upon the susceptibility of the particular patient, the rate and depth of breathing, the rate at which the ethyl chloride is vaporised, the proportions existing between the

[1] *Brit. Med. Journ.*, 17th March 1906.

quantity of anæsthetic vaporised, and the quantity of incarcerated expired air, and other factors. Ethyl chloride anæsthesia is liable to deepen after the removal of the inhaling apparatus, particularly if the breathing be in any way obstructed. This postponed effect, which is of importance in children and weakly subjects, is due to the continued absorption of vapour from the lower air-passages.

As regards the **length of the available anæsthesia** after a single administration of ethyl chloride, much will depend upon the quantity of anæsthetic used and the duration of the administration. In 77 dental administrations by means of an Ormsby's inhaler McCardie found the average induction period to be 51 seconds and the average available anæsthesia to be 71 seconds. In 197 tonsil and adenoid cases the average induction period was 52 seconds and the subsequent anæsthesia about 64 seconds.

D. THE PROLONGATION OF ETHYL CHLORIDE ANÆSTHESIA

Up to the present time the more or less continuous administration of this anæsthetic for comparatively lengthy and major operations has not been attended by that success which would alone warrant us in recommending it for general surgical work. The drug appears, in fact, to be chiefly if not exclusively applicable for brief operations not necessitating complete muscular relaxation. It is true that McCardie and others have pushed its administration to such an extent as to maintain an absent conjunctival or corneal reflex for a considerable period, and have even secured and kept up complete muscular relaxation by its free use. It is questionable, however, whether ethyl chloride is suitable for cases requiring this degree of anæsthesia.

Should it be desired to prolong anæsthesia, the inhaler, charged with more anæsthetic, must be intermittently applied, care being taken to avoid inconvenient recovery on the one hand and overdosage on the other. In these cases a few c.c. of the anæsthetic may, from time to time, be sprayed directly into the inhaler from the spray bulb. It is often possible

to retain the conjunctival and corneal reflexes throughout the administration. McCardie states that the pupil tends to contract in lengthy cases. In most of the instances in which ethyl chloride has been administered more or less continuously, difficulty has been experienced in securing an equable and smooth anæsthesia, whilst considerable collapse has, not unfrequently, attended the recovery period. It is true that numerous statements are to be found as to the ease and safety with which prolonged anæsthesia may be secured by ethyl chloride, but our experience has not yet been sufficient to justify us in recommending this anæsthetic for lengthy operations. As regards the attainment of complete muscular flaccidity by its use, it is questionable whether there is not, at all events in many cases, considerable risk of overdosage.

Some attempts have been made to keep up ethyl chloride anæsthesia during protracted throat operations, but here again it is necessary to be cautious in recommending such procedures.[1]

E. DANGERS CONNECTED WITH THE ADMINISTRATION: FATAL CASES: POST-MORTEM APPEARANCES

Given that the patient's general condition is satisfactory, and that the administration is conducted according to the proper principles of anæsthetisation, ethyl chloride anæsthesia may be safely induced. But in patients whose general condition is highly unsatisfactory, and especially in those suffering from any respiratory embarrassment, ethyl chloride must be regarded as an inappropriate or even a dangerous drug. Moreover, even in healthy subjects, this anæsthetic may, if administered without a due regard for those principles to which reference has been made, rapidly bring about threatening or even fatal effects. If attention be not paid to such points as the provision for and maintenance of

[1] See *Lancet*, 8th July 1905. By means of a metal cylinder charged with 250 grammes of ethyl chloride, and connected by means of tubing with the oral cavity, Dr. G. A. H. Barton has kept up anæsthesia for several minutes for throat operations. The patient is placed under ethyl chloride in the usual manner, and then, by immersing the cylinder in hot water, a sufficient supply of vapour is obtained.

unembarrassed breathing, the size of the inhaling bag, the introduction into the bag of sufficient quantities of expired air, the amount of anæsthetic used,[1] and the corneal reflex and other signs of anæsthesia, dangerous symptoms may evince themselves, their nature and degree varying with the special circumstances present.

There are two rather important points in connection with ethyl chloride narcosis which help, perhaps, to explain the often unexpected incidence of dangerous symptoms under this anæsthetic. In the first place, ethyl chloride narcosis is, by the methods now in use, so rapidly induced that it is usually difficult or impossible to recognise any stages or degrees in the administration. In the second place, the appearance of the patient during full narcosis is unattended either by cyanosis or by pallor—symptoms which with nitrous oxide and with chloroform respectively indicate that a sufficiently large quantity of the drug has been given. When these two points are borne in mind it will readily be seen that unless proper care be taken, the limits of safety may readily be overstepped, and that the patient may be plunged, with few if any intervening symptoms, from a safe to a dangerous degree of narcosis.

The following account of a case in which dangerous symptoms occurred under ethyl chloride may be taken as typical of others:[2]—

8 c.c. of ethyl chloride were administered by means of an Ormsby's inhaler to a spare woman for a minor operation. There was violent struggling. Quiet anæsthesia followed. The operation was performed. The breathing was regular with slight stertor. An occasional breath of air was given. In a few moments cyanosis and arrested breathing occurred. The tongue was pulled out. There was no jaw spasm. Artificial respiration was employed. There was no wrist pulse. The colour quickly improved and breathing recommenced. Screaming and struggling followed. Breathing and pulse again became feeble, and necessitated further artificial respiration. Jaw spasm and twitching of limbs now occurred. The patient gradually recovered.

---

[1] An interesting case is referred to by Mr. A. Beresford Kingsford (*Brit. Med. Journ.*, 14th April 1906, p. 893). About 12 c.c. of ethyl chloride were inadvertently placed in an inhaling bag, and the patient almost immediately developed stertor and an insensitive cornea.

[2] *Brit. Med. Journ.*, 24th March 1906, p. 679.

A considerable number of ethyl chloride fatalities have now been recorded, and at the time of writing (May 1906) details of nineteen of these are available for consideration.[1]

The sex is stated in 17 cases; 10 were males and 7 females. This preponderance of males is similar to that met with in the case of chloroform (p. 402). The age is mentioned in 15 cases, and varied from 1 to 67 years. It is interesting to note that of these 15 fatalities only 3 occurred in children. The condition of the patient is mentioned in 14 cases. It is described as good in 5; the patient was alcoholic in 3; 1 patient was thin and the subject of sacro-iliac disease; 2 patients had marked morbus cordis; and 3 were suffering from diseases about the jaws or neck. The inhaler used is referred to in 9 cases. In 2 it was of the semi-open type; in 7, *i.e.* in the large majority of cases, it was a close inhaler. As to the symptoms displayed by the patients, it is difficult to speak with anything like certainty. In 8 of the 19 cases it is impossible to say whether the fatal phenomena were of an asphyxial or of a syncopal type. Of the remaining 11 cases 7 apparently displayed asphyxial symptoms; but in 3 of these there were pre-existing local conditions about the upper respiratory passages, which doubtless contributed to the fatalities. In one case death appears to have been caused by simple spasm of respiratory muscles. In another the asphyxial seizure took place during light anæsthesia. In several of the cases of this group cyanosis was observed. In 4 cases death apparently took place without asphyxial symptoms. In one of these the patient was a thin woman, to whom 5 c.c. of ethyl chloride were administered by an Ormsby's inhaler, and the phenomena seem to have been those of simple overdosage. There was no struggling; at the first stertorous breath the inhaler was removed; the breathing was shallow; there was no pulse; the pupils were dilated, and there were no reflexes. In another the patient was a fat, alcoholic woman, to whom 6 c.c. were administered in a modified Ormsby's inhaler. In a third case, that of a labourer, violent struggling occurred, and this was quickly followed by sudden pallor, shallow breathing, and imperceptible pulse. In the fourth case the patient was in a very bad general condition, and peripheral circulation ceased before respiration. In 5 of the 19 cases there are no post-mortem records, and in several of the other 14 cases the records are very meagre. In one case the blood is described as having had a peculiar cherry-coloured appearance. In another all the organs were observed to be markedly anæmic. As the viscera were perfectly healthy in several cases it would be illogical to attach much importance to the morbid changes found in others. At the same time, it may be mentioned that various cardiac conditions were noted in the autopsies, such as fatty degeneration of the heart, valvular affections, atheroma of the coronary arteries, and adherent pericardium.

[1] Dr. Luke of Edinburgh, to whom I am indebted for much information, has recently collected evidence of twenty-two fatalities, but details of only seventeen of these are available (*Lancet*, 5th May 1906, p. 1233).

By the courtesy and kindness of Dr. R. Salusbury Trevor the author is enabled to give a *résumé* of a post-mortem conducted on a patient of 67 who died under ethyl chloride:—Body that of a well-nourished man. Neck short. Rib cartilages ossified. Cervical veins engorged. *Thorax:* on opening, strong smell of ethyl chloride. *Lungs:* both deeply congested. Mucus in bronchi, but in small amount only. *Larynx:* chronic laryngitis ("clergyman's throat"); no obstruction to glottis. *Heart:* 17 oz.; flabby as a whole; muscle easily lacerable and very soft; dilatation of right auricle and right ventricle and of left ventricle. Mitral and tricuspid valves atheromatous but competent; muscle, marked fatty degeneration and fatty infiltration. *Vessels:* atheroma of aorta and of coronary arteries. *Abdomen:* liver slightly nutmeg and fatty. Other organs congested only. *Cranial cavity:* œdema of surface of brain. Brain congested.

Although our knowledge is at present insufficient to enable us to speak with certainty, the foregoing cases would seem to indicate that ethyl chloride may prove fatal in two distinct ways:—

(1) By **simple overdosage, ethyl chloride toxæmia**, or **ethyl chloride syncope**,[1] the prominent features of which are pallor, pulselessness, arrest of breathing, wide dilatation of pupils, general muscular flaccidity and separation of lids, these symptoms being quickly followed by, or perhaps indicating, the establishment of cardiac arrest; and

(2) By **intercurrent respiratory embarrassment** (asphyxia) depressing a circulation possibly already depressed by ethyl chloride, the prominent symptoms of this condition being spasm about the jaws, mouth, tongue, larynx, or respiratory muscles, leading to respiratory arrest with some cyanosis, the asphyxia culminating with greater or less rapidity in cardiac arrest.

Should future experience confirm this classification of ethyl chloride accidents, it would seem that there is in it something strongly suggestive of the two chief modes of death under chloroform, although there is obviously considerable difference between these two anæsthetics as regards their relative safety. The explanation of ethyl chloride being far more dangerous than nitrous oxide, and distinctly more dangerous than ether, is to be found in the fact that when freely pushed a considerable fall of blood-pressure takes place (p. 135).

[1] See a case recorded by Flemming (*Bristol Med. and Chir. Journ.*, vol. xxii.).

There is no good evidence that the sitting posture is contra-indicated under ethyl chloride unless the drug be unnecessarily pushed.[1]

Both Lotheisen and Parker have successfully treated cases of ethyl chloride syncope by inversion and artificial respiration. In Lotheisen's case recovery is stated to have taken place three minutes after apparent stoppage of the heart.[2]

It is impossible to say in what proportion of cases dangerous symptoms occur under ethyl chloride, as so much depends upon the experience of the anæsthetist, the selection of appropriate cases, and numerous other circumstances. According to McCardie, Ware met with six nearly fatal cases in 1000 administrations.[3] In four out of 150 administrations to infants under one year of age Miss Flora Murray[4] met with arrested breathing. McCardie (writing in 1906) states that he has encountered neither asphyxia nor syncope in 2000 administrations. It is impossible, in the present state of our knowledge, to attach even an approximate death-rate to this anæsthetic. McCardie believes that the mortality is about 1 in 3000.

F. AFTER-EFFECTS

One of the chief disadvantages of ethyl chloride is that its administration is not unfrequently followed by headache, nausea, and vomiting. Moreover, cases occasionally occur in which the recovery period is attended by considerable prostration or even by collapse. It is true that a short administration may usually be conducted without causing any very obvious after-effects. But in a series of short administrations it will generally be found that one patient in every five, six, or seven suffers from considerable discomfort, either immediately after the administration or some hours subsequently. The headache, which may not come on till some time afterwards, may

[1] Mr. A. Beresford Kingsford states (*Brit. Med. Journ.*, 14th April 1906, p. 893) that at the Central London Throat Hospital ethyl chloride or somnoform has been administered to 7000 sitting patients with only two cases of formal artificial respiration, in both of which recovery took place.

[2] See *Lancet*, 7th October 1905, p. 1023.

[3] *Lancet*, 7th October 1905, p. 1023.

[4] *Lancet*, 25th November 1905, p. 1543.

be intense, and the vomiting distressing. McCardie[1] has drawn attention to these cases of vomiting. In one the symptom came on six hours after the administration, and continued for twelve hours. Headache and vomiting are much more common when ethyl chloride has been administered for a comparatively protracted operation than when it has been given for a short operation, such as that of tooth extraction.

Ethyl chloride seems to be more liable than other anæsthetics to be followed by **after-collapse.** This state appears to be most likely to occur when a full dose has been given with but little air, or when the drug has been somewhat extensively employed for a protracted operation.

[1] *Lancet*, 4th April 1903, p. 953.

CHAPTER XIII

ETHYL BROMIDE, ETHIDENE DICHLORIDE, AMYLENE (PENTAL), AND OTHER ANÆSTHETICS

A. ETHYL BROMIDE

Administration and Effects produced. — The anæsthetic properties of ethyl bromide were first recognised by Nunneley of Leeds in 1849, who spoke highly of the drug. Rabuteau[1] and Turnbull[2] were the next to investigate its anæsthetic properties. The latter used it in a considerable number of cases, and has on more than one occasion brought its anæsthetic merits before the notice of American surgeons, several of whom, including Dr. Chisholm,[3] Dr. Levis, Dr. Marion Sims, and others, have employed it with more or less success. The late Sir B. W. Richardson[4] considered the bromide a good and efficient anæsthetic. Clover, however, who gave it a trial, was not favourably impressed with it.[5] Dr. H. C. Wood of Philadelphia is also opposed to its introduction into general use. Drs. Schneider and Herz,[6] as well as other German dentists, have used ethyl bromide in their practices, and speak highly in its favour for dental operations. Dr. J. F. Silk[7] has also investigated the properties of the bromide as an anæsthetic in this branch of surgery. He administered it in over 130 cases, and took notes of the effects produced. The author has

[1] *Lancet*, vol. i., 1877, p. 143.

[2] *Manual of Anæsthetics.*

[3] Dr. Chisholm has used bromide of ethyl in 3000 cases without a fatality. See *Maryland Med. Journ.*, 5th December 1880.

[4] *Asclepiad*, 1885, p. 264.

[5] *Brit. Med. Journ.*, vol. i., 1880, p. 586.

[6] *Internationale klinische Rundschau* 14th April 1889. See also *Lancet*, 27th April 1889, p. 848.

[7] *Trans. Odont. Soc. of Great Britain*, February 1891.

therefore largely availed himself of the information and conclusions contained in Dr. Silk's paper on the subject.

All who have employed ethyl bromide in surgical practice agree that it is more adapted for operations of very short duration than for others. It often produces an analgesic rather than an anæsthetic effect, and has hence been somewhat extensively used in dental practice. It rapidly destroys consciousness; and recovery from its influence is correspondingly speedy.

The administration may be conducted by means of a Rendle's mask (Fig. 34, p. 326), but an Ormsby's inhaler (Fig. 43, p. 338) is very suitable for the purpose. A drachm, or a drachm and a half, should be placed upon the sponge of this inhaler, and the apparatus applied to the face of the patient. Dr. Silk recommends that little or no air should be admitted for the first few inhalations, after which the air-cap of the apparatus may be opened. With regard to the time occupied in producing anæsthesia, Dr. Silk found this to be, on the average, 66 seconds; whilst the duration of anæsthesia was 46 seconds. When the inhalation exceeded two minutes, the after-effects were liable to be troublesome. Of 300 cases in which Dr. Chisholm administered ethyl bromide the time required to produce deep anæsthesia was not more than 60 seconds.

As to the signs of anæsthesia, the administration should be conducted till softly snoring breathing, or insensibility of the cornea, is produced. Should there be delay in the supervention of these signs, the inhaler must be removed on the detection of any feebleness or irregularity in the pulse. A single and continuous administration in this manner is not likely to be attended by any unpleasant after-effects; but a reapplication of the inhaler may induce nausea and vomiting. An intermittent administration, such as that which would be necessary for a prolonged operation, is therefore not to be recommended. Dr. Marion Sims[1] performed Batty's operation, using ethyl bromide as the anæsthetic, and the administration lasted $1\frac{1}{2}$ hours. Vomiting occurred several times; the conjunctiva

[1] See a paper read before the New York Academy of Medicine, March 1880, entitled "The Bromide of Ethyl as an Anæsthetic." By J. Marion Sims, M.D.

was sensitive from the beginning to the end; opisthotonos, very rapid breathing, and violent straining were produced. Severe pain in the head followed the inhalation, and after attacks of diarrhœa, tenesmus, and convulsions, the patient died (21 hours after the operation). Dr. Levis of Philadelphia administered the bromide for 40 consecutive minutes with an expenditure of 11 drachms. Other observers also record prolonged administrations.[1]

When ethyl bromide is administered as above recommended, respiration is generally well maintained. It may, however, become temporarily embarrassed by spasm of the masseters and adjacent muscles.[2]

Professor Wood of Philadelphia regards ethyl bromide as a cardiac depressant. During its administration the pulse usually becomes increased in rate, and somewhat diminished in force. In several of the patients to whom Dr. Silk administered this agent, he found that distinct irregularity and slowing of the pulse were to be detected.

Struggling and excitement are exceptional. Dr. Turnbull records hysterical excitement in 6 out of 100 cases. This absence of early excitement is doubtless a great point in favour of the bromide. The pupils usually dilate during the administration, and profuse salivation and sweating are not uncommon.

Dangers connected with the Administration.—Several deaths have occurred during or immediately after the administration of this anæsthetic; but as it is difficult or impossible to ascertain the number of times ethyl bromide has been employed, the actual death-rate is unknown. Some authors state that it is about 1 in 5000. There is good reason to believe that the risks attendant upon the administration have been over-estimated, and that if a pure drug be employed, and ordinary care exercised, the rapid induction of anæsthesia sufficient for the performance of a short operation is attended by little or no danger. Dr. Silk, who has investigated all the published fatal cases, says that in some of these (1) sudden and early heart-failure occurred; in others (2) respiratory paralysis took place

[1] See Norton, *Brit. Med. Journ.*, 15th May 1880, p. 735.
[2] See an article by Brown Kelly, *Brit. Med. Journ.*, 30th April 1902, p. 590.

somewhat later in the administration; and in others again (3) gastro-intestinal symptoms were recorded. Gleich[1] reports a case in which the face became cyanotic and pulse and respiration ceased together. The post-mortem showed no hyperæmia of the brain, but there was fatty degeneration of all the viscera. A fatal administration is also reported in the *Dental Cosmos*, August 1880. Jendritza[2] refers to a case in which unconsciousness, trismus, and dilated pupils came on after recovery from this anæsthetic administered for tooth-extraction, the condition lasting 90 minutes.

After-Effects.—As with other agents, the after-effects bear a kind of proportion to the duration of the anæsthesia. A short administration is usually not followed by headache or nausea, the patient regaining consciousness very satisfactorily. It is not uncommon, however, for some degree of depression to be experienced, and in some cases actual fainting has been recorded. Hysterical outbursts may sometimes follow the inhalation. Nausea and vomiting are exceptional after a single administration; but they are not uncommon during or after a comparatively long inhalation.

Looked at from all points of view, ethyl bromide can hardly be regarded with much favour. As compared with nitrous oxide it is distinctly inferior not only in point of safety, but in the greater liability after its administration to headache, nausea, and other unpleasant effects. Before any very definite opinion, however, can be expressed as to its suitability for use in dental and other minor surgical operations, a more extensive trial of the drug should be made. Its greater portability is necessarily a recommendation when we compare it with nitrous oxide; but its liability to decomposition quite outweighs this advantage.

B. ETHIDENE DICHLORIDE

Administration and Effects produced.—Ethidene dichloride was first employed as an anæsthetic by Snow,[3] who

[1] *Deutsche med. Zeitung*, Berlin, August 1892.
[2] *Year-Book of Treatment*, 1897, p. 172.
[3] Most of the information which is here given concerning ethidene dichloride is derived either from the reports of the Glasgow Committee on Anæsthetics

administered it on several occasions with good results. Snow found the effects to be nearly the same as those of chloroform. In 1870 it was used by Liebreich and Langenbeck in Berlin,[1] and by Sauer[2] and Steffen.[3] In 1879 the Glasgow Committee of the British Medical Association[4] drew attention to the merits of the anæsthetic, and, after a careful comparison of its action with that of chloroform, published their results in the following year. Fifty operations were performed under ethidene dichloride, fifty under chloroform, and the results tabulated. They found the average dose of ethidene to be 40·3 c.c., or 1·8 c.c. for each minute during which the patient was under its influence. With chloroform the average dose was 31·8 c.c., or 1·7 c.c. per minute. The time taken to produce anæsthesia was, in the case of ethidene dichloride, 4·3 minutes; whilst with chloroform it was 5·4 minutes. Less excitement was observed than with chloroform. The Committee found that both the pulse and the respiration under ethidene dichloride were less altered than when chloroform was used. They did not obtain the marked slowing of the pulse and the quick respiration which are often observed with chloroform. Ethidene dichloride was regarded by the Committee as midway, in point of safety and in other respects, between chloroform and ether; and after their favourable account of its action it was for a time largely used. Mr. Tom Bird[5] has recorded six administrations by means of Junker's apparatus. Mr. J. H. Palmer[6] has also reported his experiences with the agent administered upon lint or by means of a towel. He found that one ounce was required to anæsthetise a boy of eighteen for an operation lasting 35 minutes. We are indebted, however, to Clover[7] for the records of no less than 1877 administrations of ethidene dichloride, and his results are of great interest. Of the 1877 administrations, 287

(*Brit. Med. Journ.*, 18th December 1880, p. 958); from a lecture given by the late Mr. Clover (*Brit. Med. Journ.*, 29th May 1880, p. 797); or from Dr. Snow's article on "Monochlorurretted Chloride of Ethyle" (*op. cit.* p. 420).

1 *Berlin. klin. Wochenschrift*, Nos. 31 and 33, 1870, p. 401.

2 *Pharm. Centralblatt*, vol. xiv. p. 140.

3 *Deutsche Klinik*, No. 44, p. 398; and *Jahresb. der Medicin*, 1870-1-2.

4 *Brit. Med. Journ.*, vol. i., 1879, p. 108.

5 *Med. Times and Gaz.*, vol. i., 1879, p. 62.

6 *Lancet*, vol. ii., 1879, p. 637. Mr. Palmer obtained his ethidene from Kahlbaum of Berlin, through some London chemists.

7 *Brit. Med. Journ.*, 29th May 1880, p. 797.

were for major operations. Clover usually preceded the administration of ethidene by nitrous oxide gas, using his combined gas-and-ether inhaler for the purpose. The vapour of ethidene was gradually added when the patient was partly anæsthetised by nitrous oxide. By this method struggling was rarely met with. A little convulsive twitching occurred as anæsthesia approached, and this was quickly followed by stertor and dilatation of the pupils. Air was then admitted as occasion required; and the quantity of ethidene given was regulated by the general condition of the patient. Clover seems, in fact, to have administered ethidene in very much the same way as he employed ether, *i.e.* with a limited supply of air.

Dangers connected with the Administration.—Sauer, to whom reference has already been made, has recorded a fatality under ethidene dichloride in a patient who was the subject of morbus cordis. Another fatality is reported by Clover[1]; but from the published account of the case the anæsthetic seems to have had but little share in bringing about the fatal syncope which followed the administration. The patient had a large flabby heart, and syncope took place whilst the head was being voluntarily raised after the operation was over. A third case is put on record by Dr. Mouillot.[2] The patient was the subject of empyema, and died with symptoms of syncope soon after the stage of struggling. A fourth fatality is mentioned[3] as having occurred during an ophthalmic operation. Pallor and disappearance of the pulse were noticed at the moment the cornea was incised. It may be incidentally mentioned that ethidene dichloride seemed at one time to be specially suited for ophthalmic operations, owing to the infrequency of struggling during its administration, and of vomiting afterwards. There can be no doubt, however, that this anæsthetic, although more stimulating than chloroform, is to be regarded in this respect as inferior to ether. Clover refers to three cases in which alarming symptoms presented themselves during the administration, and in his remarks on the fatality above alluded to, states his belief that ether would have been safer than ethidene dichloride.

[1] *Loc. cit.* [2] *Brit. Med. Journ.*, vol. i., 1881, p. 385.
[3] *Ibid.* vol. ii., 1882, p. 1267.

After-Effects.—According to Clover, patients recover from ethidene dichloride anæsthesia very satisfactorily. He found vomiting to occur in one-third of his administrations for major operations, and in one-twentieth of those for minor operations. He further states that vomiting after this anæsthetic invariably ceases sooner than after chloroform. Of thirty-three cases mentioned by Sauer, two vomited, and two had nausea and headache after. The Glasgow Committee found that nausea and vomiting were about equal in frequency after ethidene dichloride and after chloroform, but that vomiting after the former agent was of shorter duration than that after the latter.

C. AMYLENE. PENTAL

Amylene

Administration and Effects produced.—For most of our present knowledge concerning the effects produced by amylene we are indebted to Snow, who, as already mentioned, was the first to employ this substance as an anæsthetic. Snow used it in 238 cases, and found that the best results were obtained by administering it with his chloroform inhaler (p. 411). The great volatility of amylene almost necessitates the use of some special apparatus. Snow found that three to four fluid drachms were required to cause insensibility in the adult, and that it was necessary to employ an atmosphere containing about 15 per cent of the vapour. Amylene appears to differ from chloroform in that the continuous administration of a very dilute vapour does not lead to anæsthesia; it is necessary to exhibit the agent in a somewhat concentrated form. Owing to the sparing solubility of amylene in the blood, and to its great volatility, patients very rapidly emerge from its influence, so that a frequent renewal of the inhalation is necessary. Snow estimated that amylene was consumed at about the rate of one fluid drachm per minute, when administered by means of his apparatus.[1]

In most of Snow's administrations an analgesic and not a truly anæsthetic state appears to have been obtained. He

[1] *Med. Times and Gaz.*, 17th January 1857, p. 60.

declared, indeed, that he found it possible to secure an absence of pain with a less profound coma than that which characterised the use of chloroform or ether. The lid-reflex was not, as a rule, abolished, although muscular movements in reflex response to operative interference were usually absent. Both major and minor operations were performed during this comparatively light form of anæsthesia. The pulse was almost always increased in frequency and force. The respiration was often accelerated. The pupils were most commonly about the ordinary size. The colour of the features was heightened. Perspiration was met with in some cases. It was found that amylene could not be depended upon for producing complete muscular relaxation, and that it was not a very convenient anæsthetic for prolonged operations about the mouth or face. It appeared to answer best in short operations not requiring muscular flaccidity, such as those for the extraction of teeth. Less salivation was observed than under ether or chloroform.

Soon after the introduction of amylene by Snow, it was tried somewhat extensively both in this country and abroad. The conclusions arrived at by a Committee of the Academy of Medicine were [1]: That rigidity was the rule rather than the exception during amylene administrations; that a remarkably rapid recovery from its effects occurred; and that it was more suitable for brief operations than for others. Its unpleasant odour was regarded as a barrier to its general employment. M. Giraldès administered amylene to 79 children, and stated that two drachms were required in most cases to produce insensibility to pain. According to Kappeler,[2] amylene was given a fair trial by Spiegelberg and Lohmayer, who were unable to obtain complete anæsthesia with it; whilst Billroth and Jüngken found it answered well as an anæsthetic, even in major operations (resection of os calcis, amputation of leg, etc.).

Dangers connected with the Administration.—In Snow's 238 cases there were two fatalities; but in discussing these by the light of our present knowledge it is questionable

[1] See *Med. Times and Gaz.*, vol. i., 1857, p. 623.
[2] *Op. cit.* p. 192.

whether they should be directly attributed to the influence of the anæsthetic. The occurrence of these two fatal cases had the effect of lessening the confidence of the profession in the new anæsthetic; and it does not appear to have been again employed, at all events as amylene. The body subsequently introduced as pental will be discussed below.

After-Effects.—Patients recover with remarkable rapidity from the effects of amylene. Nausea and vomiting are quite exceptional. Of Snow's 238 cases there were only two in which vomiting occurred immediately after the administration; and sickness was only heard of subsequently in eight or ten cases.

Pental

The substance known by this name has been already referred to on p. 36. What the precise differences between it and its predecessor amylene may be, further experience must decide. Pental has been somewhat extensively used in Germany as an anæsthetic in dental surgery, and the following remarks, for most of which the author is indebted to Mr. T. E. Constant,[1] apply to its employment in that branch of practice.

Administration and Effects produced.—A Clover's ether inhaler, or some similar apparatus, answers best. Two drachms, or a little more, should be poured into the reservoir. The bag being attached, the patient's expirations may be allowed to partly fill the bag. The indicator must be turned to "1" when the apparatus is applied to the face. No more air is given, but the patient breathes to and fro for about 40 seconds, the indicator being progressively pushed towards "F." The symptoms produced are similar to those recorded by Snow. The face flushes, the pulse becomes quicker and quicker, the pupils dilate, the eyes are fixed and open, the conjunctival reflex disappears, the breathing is quick and laboured, and there is slight cyanosis. There may be some opisthotonos. At the end of about 40 seconds, the inhaler is removed and the extraction commenced. Anæsthesia is

[1] The pental used by Mr. Constant was procured from C. A. F. Kahlbaum of Berlin.

stated to persist for about a minute after the removal of the face-piece. It is sometimes possible to obtain true analgesia, the patient retaining consciousness whilst a tooth is being painlessly extracted.

Dangers connected with the Administration.—Several fatalities in connection with the use of pental have been recorded.[1] A case has also been reported to the author in which the most alarming symptoms occurred immediately after the inhalation. Respiration grew shallow and then ceased, whilst the radial pulse became imperceptible. Inversion restored the pulse; but artificial respiration for 7 minutes had to be resorted to before recovery ensued. Looked at from all points of view, the use of amylene or pental seems to have but little to recommend it. As compared to nitrous oxide for brief operations it is certainly inferior, not only because of its greater danger, but because it is not so agreeable to inhale.[2]

After-Effects.—As with the amylene employed by Snow, after-effects are usually completely absent.

D. NITROGEN

Nitrogen is capable of producing insensibility to pain when inhaled free from oxygen, or with very small percentages of that gas. The anæsthesia must be regarded as the result of oxygen-deprivation, for it is obvious that we cannot assign any specific anæsthetic properties to nitrogen itself. In 1868[3] Burdon Sanderson, John Murray, and Smith Turner administered nitrogen for tooth-extraction to six patients at the Middlesex Hospital. In the first two cases a considerable quantity of air appears to have been breathed with the nitrogen; and even in the remaining four cases there is good reason to believe, from the results obtained, that in some way or another unknown quantities of oxygen must have gained access to the lungs during the administration. Thus, insensibility did not occur till from 3 to 4 minutes after the commencement of the inhalation; no lividity of the features was

[1] See *Brit. Journ. Dent. Science*, 1st and 15th June 1892; *Lancet*, 4th Jan. 1896, p. 45; *Dental Record*, Nov. 1893, vol. xiii. p. 511.

[2] For further remarks see *Wiener klin. Woch.*, 21st and 28th Jan. 1892.

[3] See *Brit. Med. Journ.*, 13th June 1868, p. 593.

observed; and in only two of the four cases was there an absence of pain during the operation.

In the year 1890, at the request of the late Sir George Johnson, the author administered nitrogen with ·5 per cent of oxygen (*i.e.* practically pure nitrogen) to nine patients at the Dental Hospital, London. There was no excitement in any case. An onlooker could not have detected any difference between the phenomena produced and those usually met with under nitrous oxide. The author used the same apparatus as that he employs for nitrous oxide (Fig. 22, p. 269), and took great care that the face-piece fitted well and that the valves worked accurately, so that no air whatever might gain admission to the lungs. Anæsthesia was produced with remarkable rapidity in each case. The available period of anæsthesia for a dental operation was, with one or two exceptions, shorter than with nitrous oxide. There was reflex screaming in some of the cases; but this is common under nitrous oxide, especially in hospital practice. The nitrogen was administered in each case till slight epileptiform movements appeared. The recovery was quick and good. There was no nausea or vomiting. The pulse was usually rapid, and the author is inclined to think not so strong as under nitrous oxide.

The author also administered nitrogen with 5 per cent of oxygen to five cases; and nitrogen with 3 per cent of oxygen to four cases. A longer time was taken to produce anæsthesia than with the practically pure nitrogen; but the period of inhalation was still remarkably short. The resulting anæsthesia seemed to be longer than that obtained by nitrogen alone. No excitement was noted in any case. During the administration there was less jactitation in these than in the preceding nine cases. In one case three teeth were painlessly extracted. There was some excitement after the inhalation in a few of the cases. One patient, a boy, complained of much headache, and cried with pain. In one case there was rapid tremor of one arm after the administration. This phenomenon was also observed in one of the pure nitrogen cases. All patients exhibited jerky and irregular breathing and cyanosis.

On a subsequent occasion the author administered nitrogen

with 5 per cent of oxygen to one case. The anæsthesia was not satisfactory. On the same day he administered to two cases nitrogen with about 6·6 per cent of oxygen. There was a longer period of inhalation than with the 5 per cent of oxygen, and some apparent discomfort. In one of these cases the administration was pushed till slight clonic movements, irregular respiration, and cyanosis occurred. The anæsthesia was then complete for a short operation.

Finally, nitrogen with 7 or 7½ per cent of oxygen was administered to two patients. In both there was distinct anæsthesia. In one case, that of a woman, there was no jactitation, but some cyanosis, and the patient was quiet throughout. In another patient, also a woman, the symptoms were like those of pure nitrogen or nitrous oxide, coming on more quickly. There was definite anæsthesia.

Sir George Johnson, in his report of the above administrations of nitrogen with ·5 per cent of oxygen, stated that "the maximum period required to produce anæsthesia was 70 secs., the minimum 50 secs., and the mean time 58·3 secs." With regard to the cases in which 3 per cent of oxygen was present, he stated that "the time required to produce anæsthesia varied from 60 to 75 secs., the average time being 67·5 secs." Referring to the cases in which 5 per cent was present, he stated that "the time required for the production of anæsthesia ranged from 75 to 95 secs., the average being 87·5 secs."[1]

E. METHYL OXIDE

Methyl oxide, or methyl ether, $(CH_3)_2O$, is a gas which, when perfectly pure, has a pleasant, fruity odour. It has a specific gravity of 1617 (referred to air), and is readily liquefied under slight pressure. It is very soluble in ethylic ether. Richardson[2] conducted some administrations with methyl oxide thus dissolved, and doubtless obtained a mixed effect partly due to methyl oxide and partly to ordinary ether.

[1] For further information see *Lancet*, 11th April 1891, p. 815. Details will here be found of other cases in which Mr. Woodhouse Braine administered nitrogen.

[2] See *Med. Times and Gazette*, 30th May and 6th June 1868, pp. 581 and 609; see also *Asclepiad*, vol. ii. p. 270, and vol. iv. p. 135.

Wishing to ascertain the **effects** of the pure substance, and being fortunate enough, through the kindness of Mr. J. Addyman Gardner, to obtain a sufficient quantity of it for clinical purposes, the author anæsthetised several patients with this anæsthetic in the dental department of St. George's Hospital.[1] Unfortunately the results were not so satisfactory as one had hoped they might be, but they were nevertheless of interest. In some cases a mixture of about 33·3 per cent of methyl oxide to 66·6 per cent of air was employed; in others a 50 per cent mixture. It was found that when methyl oxide was largely diluted with air the mixture, which was not unpleasant to inhale, did not produce a satisfactory form of anæsthesia. On the other hand, mixtures sufficiently concentrated to produce satisfactory anæsthesia were too pungent to be pleasant. As compared to the anæsthesia obtained by the recognised anæsthetics, that produced by methyl oxide was of a lighter type and was more liable to be followed by nausea and distress. Although a comparatively long anæsthesia was attainable by a prolonged administration, unpleasant after-effects resulted. For further information the reader is referred to the original account of these cases.

F. OTHER ANÆSTHETICS

Ethylene, or **olefiant gas,** was administered by Nunneley of Leeds in 1849 to four patients; but it was found to be unsatisfactory in its action.

Amyl hydride,[2] **amyl chloride,**[3] **ethyl nitrate,**[4] **benzene,**[5] and **turpentine**[6] have one and all been found to be capable of producing general anæsthesia when administered in the form of vapour.

[1] For a full account of this work see the *Lancet*, 19th Nov. 1904, p. 1408.

[2] *Lancet*, vol. i., 1885, p. 101; *Asclepiad*, 1885, p. 168; *Med. Times and Gaz.*, 28th Dec. 1867, p. 694.

[3] Kappeler, *op. cit.* p. 190.

[4] Snow, *Med. Times and Gaz.*, 17th Jan. 1857, p. 61.

[5] Snow and Richardson, *Med. Times and Gaz.*, 17th Jan. 1857, p. 61; and 28th Dec. 1867, p. 694.

[6] *Med. Times and Gaz.*, 28th Dec. 1867, p. 694; and Kappeler, p. 193.

CHAPTER XIV

ANÆSTHETIC MIXTURES

MIXTURES consisting of chloroform and alcohol, of chloroform and ether, and of chloroform, alcohol, and ether, have been very extensively employed not only in this country but upon the Continent. The object in adding alcohol and ether to chloroform has been, not only to prevent too concentrated a chloroform vapour from being respired, but to counteract any tendency to circulatory depression. By mixing a small quantity of alcohol with chloroform it is obviously possible to administer a chloroform vapour considerably weaker than that which would result were the undiluted agent administered in precisely the same manner; whilst mixtures of ether and chloroform have been shown, by comparative experiments, to produce a better cardiac action than chloroform alone.[1] There is, however, a theoretical objection to these mixtures, and one which Snow particularly laid stress upon. It is that as the constituents have their own special rates of vaporisation, the more volatile ingredients will first tend to vaporise, the less volatile remaining behind to be subsequently respired. Ether and chloroform, for example, have very different boiling-points, whilst the rates of diffusion of their respective vapours will follow the same law as that which obtains in the case of gases—that is to say, they will be inversely as the square roots of the densities of those vapours. It is therefore clear that in using a mixture of equal parts by volume of liquid ether and chloroform, not only will the proportions of the anæsthetics in the mixed vapour be different from those in which the liquids were mixed, but there will be fluctuations in these proportions throughout the ad-

[1] *Trans. Roy. Med. Chir. Soc.*, vol. xxix., 1864, p. 342.

ministration. In actual practice this separate vaporisation of constituents does not, as a rule, give rise to the irregular effects which might be anticipated, probably because it is customary to administer anæsthetic mixtures in small quantities at a time and to frequently replenish the inhaler. Ellis overcame the objection in question by devising an apparatus which contained the anæsthetics separately, and their vapours were mixed in the desired proportions during the administration. The plan was very ingenious, but too complicated for general use. There is another way, however, in which the objection above referred to may, to a great extent, be overcome, at all events in the case of certain mixtures, viz. by employing such proportions of the liquid constituents as will evaporate in the same period of time at the same temperature. When it is impossible to adjust the proportions in this manner, the anæsthetist must proceed as above suggested and administer small quantities of the mixture at a time, and frequently replenish the mask or inhaler, thus endeavouring, as far as possible, to vaporise one dose before another is added.

A. MIXTURES OF CHLOROFORM AND ETHYLIC ALCOHOL

Sansom[1] recommended and used **equal parts of chloroform and alcohol**, and believed that the good effects he obtained were due to the alcohol restraining the volatility of the chloroform, and thus preventing too concentrated a vapour. Others, including Snow, have employed this mixture with success.[2] When alcohol is used with chloroform it is, however, generally added in smaller proportions, *i.e.* to the extent of **one-fourth** or **one-fifth**. If one-fifth of alcohol be added, and the mixture be administered by means of a Junker's inhaler, it will be found difficult to anæsthetise vigorous or alcoholic subjects, although more susceptible patients will be readily affected. In the course of an experimental research Schäfer and Scharlieb[3] found that by adding one part of absolute

[1] *Medical Times and Gazette*, vol. ii., 1870, p. 107.
[2] See Stephens, *British Medical Journal*, January 1888, p. 19.
[3] *Trans. Roy. Soc. Edin.*, vol. xli. part ii. (No. 12).

alcohol to nine parts of chloroform the ordinary fall of pressure met with under the latter anæsthetic was largely prevented, and that respiration was less depressed than with chloroform itself. They also found that recovery took place more readily after this mixture than after chloroform. Better results were obtained with mixtures containing **one-tenth** than with those containing one-fifth of alcohol. The beneficial effects, according to these observers, are not due to the mere dilution of the chloroform vapour; for with ether instead of alcohol the blood-pressure tracings were similar to those of pure chloroform. They believe that the alcohol produces a stimulant effect upon both heart and respiration.

Mixtures of alcohol and chloroform should be **administered** in precisely the same manner as the undiluted anæsthetic.

B. THE "C.E. MIXTURE" AND OTHER MIXTURES OF CHLOROFORM AND ETHER

The C.E. Mixture

For several years the author has extensively used a mixture of two parts of chloroform and three parts of ether, that is to say, the "A.C.E." mixture without its alcohol. For purposes of brevity and description this is spoken of in these pages as the **"C.E." mixture**. Although the presence of alcohol is generally supposed to be essential in order that ether and chloroform may remain perfectly mixed, the author has been unable to satisfy himself of the supposed advantage. In actual practice, indeed, he believes that he obtains better results with the C.E. than with the A.C.E. mixture. There is apparently less excitement during the administration and a more satisfactory recovery afterwards—differences which are probably dependent upon the absence of the alcohol.

For the **administration of the C.E. mixture to children and very feeble adults** a Skinner's mask (Fig. 55, p. 384) will suffice. For **ordinary adult subjects** this mask, which is an excellent one for the first minute or two of the administration, must be replaced either by a Rendle's mask (Fig. 34, p. 326), or

preferably by the inhaler shown in the accompanying Figure. Reference was made to this last-named inhaler when discussing the administration of ethyl chloride, for which anæsthetic it is also well adapted.

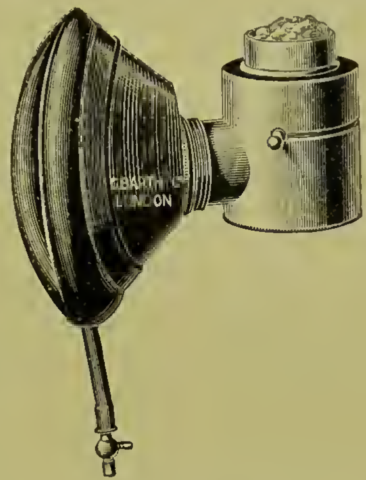


FIG. 62.—The author's C.E. Inhaler.

It consists of a face-piece identical with that used with the wide-bore ether inhaler already described (p. 334), and a simple cylindrical metal chamber with an open chimney at its upper part. The chamber contains a coarse-meshed sponge upon which the mixture may be sprinkled or poured from time to time. The sponge should be carefully chosen and, when moist and expanded, should be very slightly larger than the chamber, so that it projects somewhat into the open chimney, as in the figure. The inhaler is so made that it can only be conveniently used when the patient's head is turned to one side—the proper position in anæsthetisation. The end opposite to the chimney end is closed by a loosely-fitting circular plate, so that if too much of the mixture be poured upon the sponge, the excess simply drains out and trickles upon the hand of the anæsthetist. The mixture cannot run back upon the patient's face.

The mixture is added in small quantities at a time from a drop-bottle as shown in the accompanying figure (Fig. 63). Should any delay occur in obtaining full anæsthesia, the anæsthetist may loosely cover the chimney by his half-closed hand. It is better to have to adopt some simple procedure of this kind in order to *increase* the potency of an inhaler than to have to adjust its action with a view to a *decrease* in potency. If used as shown in the figure, *i.e.* without any restriction in

FIG. 63.—The author's C.E. Inhaler in use.

its air supply, this inhaler errs rather on the side of underdosage than on the side of overdosage, and is hence a safe inhaler so far as any risk of a too concentrated chloroform atmosphere is concerned. The author has used this apparatus largely, and to his complete satisfaction, for about two years. He has not had a single case of overdosage. Even though the sponge be saturated with the mixture it seems to be difficult to overdose an adult patient. This is probably owing to the existence of proper proportions between the volume of air entering the large chimney during inspiration and the volume of chloroform vapour which becomes mixed with that air. In order to keep the sponge uniformly moistened, the cylinder may be inverted from time to time during the administration, so that the chimney sometimes points downwards. The author has obtained better results with this inhaler than with Rendle's mask. The latter is more liable to allow overdosage to oecur and to blister the faee from the mixture soaking into the domett lining of the inhaler.

The **effects produced** by the C.E. mixture thus administered are very satisfactory. It is, of eourse, impossible to completely eliminate the stage of excitement in all cases; but by gradually administering the mixture, this stage rarely becomes ineonveniently pronounced. As a general rule women pass into deep anæsthesia without any struggling. The state of "false anæsthesia" is far less common than with chloroform. It is generally advisable to take from five to eight minutes in producing anæsthesia: if the administration be hurried, breath-holding and struggling will tend to arise. Except in the ease of obese, thick-necked, muscular, or alcholic subjects, the transition from the seeond to the third degree of anæsthetisation is usually unattended by cough, hampered breathing, or cyanosis. When full anæsthesia has been seeured, the respiration is generally regular and softly snoring, the pulse full, soft, and somewhat quicker than the chloroform pulse, the eolour good, the corneæ insensitive, the pupils of moderate size, and the muscular system flaccid. The ocular eonditions are very similar to those observed under ehloroform. The respiration, the lid-reflex, and the pupil are the best guides as to the depth of anæsthesia. High-pitched crowing breathing must

be carefully treated. As a general rule the anæsthetic should be withdrawn for a while and the lips briskly rubbed (p. 555); but if the condition be obviously associated with imperfect anæsthesia, as will be ascertained by other signs, the administration may be cautiously continued, being at once stopped if the crowing does not subside. The anæsthesia of the C.E. mixture as already indicated (p. 207) is particularly appropriate in abdominal surgery. The after-effects of the mixture appear to be slightly more pronounced than those of chloroform.

The cases in which the C.E. mixture may with advantage be used have been considered in Chaps. V., VI., and VII.; whilst the sequences containing this mixture as a constituent will be dealt with in the following chapter.

The **signs of overdosage** by the C.E. mixture are similar in their main features to those observed in the case of chloroform. Other things being equal, surgical shock is apparently less likely to arise under this mixture than under chloroform.

It is sometimes useful in certain desperate cases to administer **oxygen in conjunction with the C.E. mixture.** This may be very conveniently done as represented in Fig. 44 (p. 341).

Other Mixtures of Chloroform and Ether

A mixture consisting of **one part of chloroform and two parts of ether** was examined and used by the Committee of the Royal Medical and Chirurgical Society, who found it to be very similar in its action to the A.C.E. mixture referred to below. Ellis,[1] in his inquiries into anæsthetic mixtures, considered it very unreliable, as it parted with its ether rapidly, and with its chloroform very slowly. A death under its influence has been reported.[2] Dr. Edgar B. Truman[3] has investigated this mixture from a chemico-physical point of view, and his results are very interesting. He concludes that during the initial stages of its administration 100 volumes of ether vapour to ·95 volumes of chloroform would be inhaled;

[1] *Medical Times and Gazette*, vol. i., 1867, p. 246.
[2] *Ibid.* No. 849, p. 378.
[3] *Lancet*, 16th Feb. 1895.

whilst at the last, 100 volumes of ether to 75 of chloroform would be breathed.

A mixture containing **one part of chloroform and three parts of ether**, often known as **the Vienna mixture**, has been extensively used abroad, a large number of administrations having been recorded without a casualty. Observers in this country, however, have stated that it is uncertain and irregular in its action.[1]

A mixture consisting of **one part of chloroform and four parts of ether** was examined by the Committee above mentioned, and was reported to be very similar in its action to ether itself.

These mixtures of chloroform and ether should be administered by means of "open" or "semi-open" inhalers, such as those represented in Figs. 55 and 34. Bag-inhalers should not be employed. The greater the proportion of chloroform, the nearer should the mode of administration approach to that described on p. 385. Above all, frequent additions of small doses are essential. Some anæsthetists[2] employ Junker's system of administration (p. 376), using one bottle for ether and one for chloroform, and varying the proportions of the two vapours from time to time.

C. THE A.C.E. MIXTURE AND OTHER MIXTURES OF ALCOHOL, CHLOROFORM, AND ETHER

The A.C.E. mixture consists of one part of alcohol, two of chloroform, and three of ether. It was originally suggested and used by Dr. George Harley. Some years later the Committee of the Royal Medical and Chirurgical Society made a careful trial of it, and with very favourable results. They recommended it as preferable to chloroform; and this recommendation is to a great extent accountable for the extensive employment of the mixture. According to the Committee, the specific gravities of the constituents should be—

Alcohol	·838
Chloroform	1·497
Ether	·735

[1] *Lancet*, vol. ii., 1782, p. 828.
[2] See Tyrrell, *Clinical Journ.*, 26th Jan. 1898.

Martindale states[1] that by employing—

Alcohol	sp. gr.	·795	1 part,
Chloroform	„	1·497	2 parts,
Ether	„	·720	3 parts,

he obtains a mixture which volatilises uniformly.

When freshly prepared from the purest ingredients, and inhaled gradually with plenty of air, the A.C.E. mixture possesses an agreeable, somewhat fruity odour. It is more stable than is usually supposed, and it is quite possible that some chemical change, of which we are at present in ignorance, takes place when the alcohol, chloroform, and ether are mixed. The A.C.E. mixture should be freshly prepared, and kept in small, tightly-stoppered bottles.

The **administration of the A.C.E. mixture** is conducted in precisely the same way as that of the C.E. mixture (p. 463); and the effects which it produces are similar in their main features to those of the last-named mixture.

The **signs of an overdose** are closely allied to those observed under chloroform. Several fatalities have occurred under the A.C.E. mixture. This is not to be wondered at, when we reflect that the mixture is very extensively employed for anæsthetising patients whose general condition is extremely unfavourable. The mixture is often chosen for those who are considered unfit for chloroform on the one hand, and for ether on the other. Then, again, the erroneous practice exists of regarding this mixture as a stable and definite body, and of administering it in large doses seldom repeated, instead of in small doses often repeated. Furthermore, in some of the fatal cases[2] a bag-inhaler has been employed.

Billroth's Mixture.—Mixtures of alcohol, chloroform, and ether, containing these agents in somewhat different proportions to those of the A.C.E. mixture, have also been employed. Billroth's mixture, consisting of one part of alcohol, three of chloroform, and one of ether, is in great favour with many Continental surgeons. It is administered very much as chloroform is administered, and is said to be rarely followed by vomiting.

[1] *Extra Pharmacopœia.*
[2] *Brit. Med. Journ.*, 24th Oct. 1891, p. 906.

D. THE SO-CALLED "BICHLORIDE OF METHYLENE," OR "METHYLENE"

Composition.—The so-called "bichloride of methylene," or "methylene," was brought before the notice of the profession in 1867 by Sir B. W. Richardson,[1] who gave it the formula CH_2Cl_2, and strongly recommended it for producing surgical anæsthesia. The "methylene" supplied by Messrs. Robbins and Co. distils over at about 127°-128° F.,[2] and the temperature is stated not to vary more than 3° from first to last during distillation. As supplied by the manufacturers, "methylene" is a colourless fluid, with an agreeable odour very similar to that of chloroform. Much discussion has taken place as to the precise chemical nature of "methylene." Whilst on the one hand Sir B. Richardson maintained that the drug sold under that name was, with the exception that it contained traces of alcohol and water, chemically pure CH_2Cl_2, very strong evidence has been adduced to show that "bichloride of methylene" is nothing more than a mechanical mixture of chloroform and methylic alcohol.

The "methylene" employed in a fatal case at Prague was carefully analysed by Professor Hofmeister,[3] who found it to be a mixture of chloroform diluted with one-fifth of methylic alcohol. This "methylene," which had come from the recognised London manufacturers, had a sp. gr. of 1·3495 at 17·1° C. (68·78° F.), commenced distilling at 47° C. (116·60° F.), and continued between 49° C. and 53° C. (120·2° F. and 127·4° F.). One-fifth of the "methylene" mixed readily with water, and gave the tests for alcohol. After separating the alcohol, the residue boiled at 59·5°-60·5° C., and the distillate had a density of 1·4885 at 17·1° C., and gave the usual tests for chloroform. As already stated (p. 137), MM. Regnauld and Villejean[4] prepared some true bichloride of methylene, and compared it with the anæsthetic fluid supplied by English makers under that name. They found that bichloride of methylene had a sp. gr. of 1·334, and a boiling-point of 40·4° C. (104·7° F.), and that it was unsuitable for producing surgical anæsthesia. Finally, they agreed with Professor Hofmeister that the English "bichloride of

---

[1] See *Asclepiad*, 1888, p. 201—"Methylene as an Anæsthetic."

[2] See *Brit. Med. Journ.* vol. ii., 1883, p. 271.

[3] *Brit. Med. Journ.*, 21st July 1883.

[4] *Comptes Rendus de la Société de Biologie*, tom. i., 1884, p. 158. See also *Bull. Acad. Med.* 2nd Sér. tom. xii. p. 568.

methylene" consisted of chloroform and methylic alcohol. Dr. Junker,[1] indeed, administered a mixture of chloroform and methylic alcohol (4 to 1) in several cases. The mixture had a sp. gr. of 1·281, and produced effects which appeared to him to be precisely similar to those observed with the so-called "bichloride of methylene."

Effects.—Whatever may be the chemical constitution of Richardson's "methylene," it certainly produces effects which deserve careful consideration from a clinical point of view. The first operation under its influence was performed by the late Sir Spencer Wells, who, after a very large experience,[2] still considered "methylene" to be superior to all other agents. For several years after its introduction into practice, it was used somewhat extensively not only in this country but on the Continent. Its rapidity of action,[3] the speedy return to consciousness after its use, and the striking rarity of after-effects rendered it specially serviceable in abdominal, ophthalmic, and dental operations. Dr. Day,[4] who administered "methylene" for Sir Spencer Wells and other surgeons in 1230 cases, most of which were cases of abdominal section, spoke in very high terms of the agent. He found that it was less likely than chloroform to cause vomiting; that it was more agreeable to inhale; that rarely more than 3 to 4 drachms were required for an operation lasting half an hour; that consciousness returned very soon after the inhalation had been discontinued; that it might be used when serious heart and lung affections existed; and that, so far as his experience went, "methylene" was the best anæsthetic. Others have spoken in similarly favourable terms.[5] There are, however, two sides to every question; and many surgeons have tried

[1] *Brit. Med. Journ.* vol. i., 1884, p. 451.

[2] See *Lancet*, vol. ii., 1890, p. 898; and vol. ii. 1877, p. 191.

[3] The author cannot agree with those who state that "methylene" is a rapidly-acting anæsthetic. It may quickly destroy consciousness when given in a somewhat concentrated vapour. But when administered by means of Junker's apparatus, 10, 15, or even 20 minutes may be required to induce anæsthesia. Indeed, not long ago, the author met with a case in which he had to resort to another agent, as he was unable to secure tranquil and perfect anæsthesia with "methylene." The drug he used was freshly prepared. The patient was a tall, vascular, and powerfully-built woman of 60. After pumping with Junker's inhaler for about 20 minutes the patient was only partially anæsthetised. The author then had recourse to the A.C.E. mixture, and in 3 minutes the patient was ready for operation.

[4] "Methylene as an Anæsthetic" (*Brit. Med. Journ.*, 14th July 1888, p. 72).

[5] *Lancet*, vol. i., 1882, p. 371.

"methylene" and have discarded it. It enjoyed, for example, a long reign at the Samaritan Hospital, but was eventually replaced by its former rival chloroform. Nussbaum of Munich, who, in 1868, had administered "methylene" 15,000[1] times without any accident, found its effects very similar to those of chloroform, but, according to Kappeler,[2] he met with considerable excitement rigidity, and nausea in many cases. Hégar and Kaltenbach, who have largely used "methylene" with Junker's inhaler, do not consider it safer than chloroform, but find less vomiting after its use. Kappeler endorses these views.

Administration.—With regard to the administration of "methylene," Junker's apparatus (p. 376) has been found to be the best for the purpose. Rendle's[3] mask (p. 326) is used by some, but with this apparatus the danger of an overdose, and of asphyxial troubles, is certainly greater than with Junker's inhaler. As the liquid is more volatile than chloroform, an open mask such as Skinner's is not so applicable. The administration should be conducted as has been already described when considering chloroform. Difficulty may be experienced in obtaining true surgical anæsthesia in many cases, especially when using Junker's inhaler. It must, therefore, be borne in mind that in operations upon very sensitive parts, and when dealing with patients who are not easily affected by anæsthetics, it may be necessary either to give more of the anæsthetic than can be administered by Junker's inhaler—that is to say, to use some other inhaler—or to change to ether, chloroform, or the A.C.E. mixture.[4] The anæsthesia produced by "methylene" is, in fact, comparatively superficial, and would hardly satisfy most surgeons of the present day.

Dangers.—Several deaths have occurred during the use of "methylene"[5]; the symptoms being almost identical with

[1] *Med. Times and Gaz.* vol. i., 1868, p. 111.

[2] *Anæsthetica*, p. 105.

[3] *Brit. Med. Journ.* vol. ii., 1880, p. 729.

[4] Two cases (rectal operations) are reported by Mr. Martin Coats, in which he found it necessary to replace "methylene" by chloroform (*see* footnote, p. 469).

[5] See *Lancet*, 23rd Oct. 1869; *Brit. Med. Journ.*, 7th May 1870; 29th April 1871; 16th Sept. 1871; 31st Aug. 1872; 12th Oct. 1872; 19th Oct. 1873: *Lancet*, 2nd Dec. 1874, p. 881; and *Brit. Med. Journ.*, 24th July 1875.

those which characterise chloroform fatalities. Inversion has been successfully tried in a case of threatened death.[1]

E. SCHLEICH'S MIXTURES

Amongst the numerous other mixtures which have been employed, those introduced by Schleich[2] in 1898 deserve notice. This observer states that by mixing chloroform, ether, and petroleum ether,[3] an anæsthetic liquid may be produced which boils between 38° C. and 42° C., according to the proportions of the ingredients, and that, by slightly adjusting these proportions in accordance with the body temperature of the patient, absorption and elimination may be so balanced that no accumulation of the anæsthetic within the circulation is possible. Theoretically, each inspiration of an anæsthetic boiling at the blood temperature would be eliminated by a corresponding expiration. Anæsthetics with high boiling-points, such as chloroform, are rapidly absorbed and slowly eliminated, owing to the temperature of the blood being below such boiling or maximum evaporation points. The more volatile the anæsthetic, the less will be absorbed by the blood in a given time, and the more rapid will be its elimination. Schleich's "No. 1" mixture consists of—

Chloroform	45 parts
Petroleum Ether	15 ,,
Ether	180 ,,

and boils at 38° C. "No. 2" consists of—

Chloroform	45 parts
Petroleum Ether . . .	15 ,,
Ether	150 ,,

and boils at 40° C. "No. 3" consists of—

Chloroform . . .	30 parts
Petroleum Ether . . .	15 ,,
Ether	180 ,,

and boils at 42° C. So far as the author is aware, these

[1] *Lancet*, vol. ii., 1876, p. 462.

[2] See *Therap. Gazette*, 1898, p. 98.

[3] It is stated that the petroleum ether should have a boiling-point between 60° and 65° C.

mixtures have not been employed in this country. A modified form of Schleich's mixture, however, has been tried in a small number of cases by Dr. R. J. Probyn Williams, and later by Dr. Silk. This consisted of—

Chloroform	1 part
Petroleum Ether . . .	1 ,,
Sulphuric Ether . . .	2 parts

The results were fairly satisfactory, and may be studied in the *Transactions of the Society of Anæsthetists*, vol. iv. p. 98. One observer[1] has published his experiences in 700 cases, and these are by no means encouraging. The weak point in Schleich's argument is the assumption that his mixtures are definite anæsthetic liquids capable of yielding definite vapours. This assumption, however, is not warranted, and although we are not perhaps justified in criticising his system of anæsthetising without having tested it, there is no reason to believe that Schleich's mixtures possess any tangible advantages over those already discussed.

F. MIXTURES CONTAINING ETHYL CHLORIDE

During the last few years several mixtures containing ethyl chloride as their chief ingredient, and possessing attractive titles such as "Somnoform," "Narcotile," etc., have been extensively exploited not only upon the Continent but in this country. "**Somnoform**"—a mixture of sixty parts of ethyl chloride, thirty-five parts of methyl chloride, and five parts of ethyl bromide—was stated by those who introduced it to be absolutely safe, and to produce an anæsthesia free from all after-effects. Its disagreeable odour, however, its tendency to decomposition, its liability, like ethyl chloride, to cause headache and vomiting, and its risk to life when administered by inexperienced persons, have combined to remove this agent from the already overcrowded list of general anæsthetics.[2] In two cases in which the author witnessed the administration of

[1] *See* Dr. Rodman's interesting paper, *New York Med. Rec.*, 1st Oct. 1898.

[2] Several deaths have taken place in connection with the use of "somnoform." For further information see *Lancet*, 19th Nov. 1904, p. 1408, and *Lancet*, 25th April 1903, p. 1168.

"narcotile,"[1] a body stated to be bichloride of methyl-ethylene, and obtained by distilling mixed ethyl and methyl alcohols with hydrochloric acid, a very unsatisfactory form of anæsthesia resulted.

Mr. Harvey Hilliard[2] speaks well of a mixture consisting of half-a-drachm of ethyl chloride in one ounce of chloroform for all cases in which the latter anæsthetic is indicated. He states that this mixture is safer than chloroform, and that the patients whom he has anæsthetised with it have displayed less excitement and a better colour, pulse, and respiration than are usually observed with the latter anæsthetic. He specially advises its use in midwifery, in patients with obstructed breathing, in operations for the removal of tonsils and adenoids, and in cases in which the sitting or prone posture has to be adopted.

G. ILLUSTRATIVE CASES

The following illustrative cases may be of interest as showing the value of the A.C.E. or C.E. mixture:—

Illustrative Case, No. 15.—(This case occurred in the practice of Mr. Marmaduke Sheild, to whom the author is indebted for the following notes.) "Patient an engine-fitter, aged 42. A brawny, heavily-built man. Neck practically obliterated by an enormous swelling, reaching from the malar bones to the sternum, livid in colour, and hard and board-like to palpation. Much dyspnœa. Face livid and bedewed with sweat. Pulse weak and quick. Unable to speak or open mouth. Nitrous oxide had been given and an exploratory incision commenced; but the man had so nearly died that the operation was abandoned. It was obvious he was suffering from pressure upon the larynx and trachea. I ordered him to be given the A.C.E. mixture in a large cone with a plentiful supply of air. I further requested that the administration should be very gradual. It was quite ten minutes before slight rigidity and struggling took place. The patient seemed unconscious to pain, but was not completely flaccid. I made a free incision on the right side of the neck. The tissues did not bleed. The deep fascia was carefully incised, and I then passed my finger behind the carotid sheath into a large abscess cavity, from which a quantity of pus gushed out. The inspiration instantly became more free, but as there was still some difficulty, I made

[1] Mr. J. Addyman Gardner, F.I.C., kindly examined a specimen of this substance for the author. He reports that it is not the bichloride of methyl ethylene, and that it seems to be a mixture of methyl chloride, ethyl chloride, and ether.

[2] *Med. Mag.*, Feb. 1906.

a free incision in the middle line about the neck. Instantly the patient began to respire deeply and easily. The anæsthetic had been discontinued at the commencement of the operation, and consciousness was returning. The man was able to speak, though with a hoarse intonation, and he expressed his gratitude at his relief. The subsequent progress of the case was perfectly satisfactory."[1]

Had this patient been placed very deeply under the anæsthetic, or had a close method of inhalation been adopted, respiration would in all probability have come to a standstill.

The C.E. or A.C.E. mixture is often of great use in patients in whom grave respiratory difficulties from other causes than tracheal narrowing are present. The following case, in which the breathing was embarrassed by the most extreme abdominal distension that the author has ever witnessed, may be quoted :—

Illustrative Case, No. 16.—F., æt. 37. Thin anxious face : slightly dusky complexion : very breathless and orthopnœic : hands cold : pulse quick and feeble : chest walls thin : abdomen enormously distended with ascitic fluid and large ovarian tumour : heart much pushed upwards. As the patient was sitting upright upon an operating-table I had to administer the anæsthetic standing upon a chair. Judged it best to work with two different stages of anæsthesia : (1) Light anæsthesia during removal of ascitic fluid ; and (2) deep anæsthesia during removal of tumour. Stage (1) conducted with A.C.E. mixture : ether tried, but not well borne. Several gallons of fluid evacuated gradually : patient analgesic rather than anæsthetic. One by one pillows removed as fluid evacuated. Breathing gradually improved. During stage (2) patient recumbent, and chloroform given on Skinner's mask. Pulse got rather weak, but improved with hot-water flushing. Subsequently weaker again. Patient removed to bed.

In cases of peritonitis, intestinal obstruction, etc., with a fixed and inactive abdomen, and some respiratory difficulty, the C.E. or A.C.E. mixture is perhaps the best anæsthetic. The following is an example :—

Illustrative Case, No. 17.—F., æt. about 19. Ill for one week with peritonitis. Abdomen distended. Slightly under morphine. Rather lethargic. Pulse fair and full, but compressible and quick. Colour good. Occasionally vomits blackish fluid. Abdominal section. Operation lasted half an hour. A.C.E. given on Skinner's mask. Took it well.

[1] An almost precisely similar case to the above is reported in the *Brit. Med. Journ.* 29th Oct. 1892. Ether was used and the patient succumbed under its influence. See also another death, *Lancet*, 23rd March 1895 (chloroform), and also *Lancet*, 21st Feb. 1903 (nitrous oxide).

After some minutes changed to ether (Clover's inhaler), but this was not well borne, so went back to A.C.E. Kept her lightly under. Nearly all the time she was as follows:—Pupils 2 mm.: some conjunctival reflex, which was allowed to disappear for a few seconds at a time: respiration fairly regular, not stertorous, but deeper and quicker than before administration: colour good: pulse quicker and quicker, getting from about 90 to 120: right hand and arm moved occasionally. She vomited once on operating-table. Whilst intestine and ovary were being manipulated respiration grew quicker, and a kind of "catch" in breathing was noted. No crowing respiration. After removal of anæsthetic colour not so good, though fair: hands warm: pulse quick: conjunctiva soon sensitive. Patient remained lethargic for some time.

As already indicated (p. 171), the C.E. or A.C.E. mixture is a valuable anæsthetic in most cases of advanced cardiac disease. It seems particularly useful when mitral stenosis is present. The three following cases occurred at the London Hospital, and the author is indebted to Mr. W. Penberthy for the notes:—

Illustrative Case, No. 18.—F., æt. 36. Mitral stenosis. Retro-uterine abscess. Operation lasted 20 minutes. A.C.E. on Skinner's mask. Went under readily, and easily kept under. Mask frequently removed for a breath or two. *The patient had formerly taken ether with a nearly fatal result.*[1]

Illustrative Case, No. 19.—F., æt. 24. Mitral stenosis. Perineorrhaphy. Operation half an hour. A.C.E. given as in previous case, with equally favourable result.

Illustrative Case, No. 20.—F., æt. 25. Mitral and aortic regurgitation. Operation on cervix uteri: 40 minutes. 13 dr. of A.C.E. mixture used on Skinner's mask. Result very good.

The C.E. or A.C.E. mixture is also about the best anæsthetic for patients with advanced emphysema and bronchitis attended by fatty degeneration and dilatation of the heart. The following case is of interest, as it was a particularly anxious one, so far as the anæsthetic was concerned. The question, in fact, had arisen as to whether it was advisable to give any anæsthetic at all. The A.C.E. mixture was selected, and fortunately it answered well.

Illustrative Case, No. 21.—M., æt. about 70: average build: looks 80. Half propped up in bed. Breathing rather hurried: expiration

[1] An interesting case in which ether almost proved fatal in mitral stenosis is reported by Mr. Arthur Jefferson (*Lancet*, 20th Sept. 1884, p. 492). Chloroform was subsequently given with good result.

distinct and audible. Respiratory movements almost wholly diaphragmatic. Chest front hyper-resonant: wheezy sounds over it. Heart sounds "flapping": an occasional murmur in apical region: much epigastric pulsation. Pulse very irregular and intermittent. Face congested: bluish-red colour. He is subject to seizures of difficult breathing and cyanosis. Has a large prostate, and catheter has to be used every 2 hours. Operation supra-pubic cystotomy. Administration lasted 35 minutes. A.C.E. mixture. Gradually given on Skinner's mask. Respiration deeper and expiration more wheezy. No distress. Pulse improved, and became more regular and fuller; but never got quite regular. Face remained flushed. Some perspiration. Muttering. Conjunctiva still sensitive. Eyes commenced turning upwards. Then slight rigidity. No struggling. Catheter passed. Little if any reflex effect. Abdominal muscles tense, and respiration jerky. Distension of rectum by bag caused slight but not inconvenient movement. Skin incision also caused slight reflex movement, but absolutely no effect on wrist-pulse. During most of administration his condition was as follows:—Conjunctiva just sensitive, once or twice insensitive: respiration wheezy, with noiseless inspiration and difficult expiration: pulse as before: pupils about 4½ mm. The hands gradually got chilly, and perspiration increased. No nausea or vomiting after.

CHAPTER XV

ANÆSTHETIC SEQUENCES

WHEN certain anæsthetics are administered in succession according to a preconcerted scheme, with the object of obtaining narcosis in as smooth a manner as possible with the anæsthetic last administered, we speak of such anæsthetics as constituting a *sequence.* Amongst the developments which have recently taken place in the subject of general anæsthesia that of employing certain sequences of anæsthetics is one of the most noteworthy. By the successive administration of appropriate agents, many of the disadvantages incidental to the simpler methods of anæsthetisation may be largely eliminated. This is well seen in some of the sequences terminating with chloroform; for, by the use of these, the struggling and excitement so common, and occasionally so hazardous during chloroformisation, may be completely prevented. But in employing anæsthetic sequences it must be remembered that in order to obtain the results desired, the closest attention must be paid to numerous details in administration. If inappropriate sequences be chosen, or if appropriate sequences be clumsily used, the most unsatisfactory results may ensue.

There are two kinds of sequences: (*a*) the **simple**, and (*b*) the **compound.** In the simple sequence two anæsthetics only are employed, one being the initial and the other the terminal agent. In the compound sequence, which is a development or extension of the simple sequence, three agents are successively administered, the first being the initial, the second the transitional, and the third the terminal agent.

(A) SIMPLE SEQUENCES

The following table shows the chief simple sequences now in use. These will be considered *seriatim.*

Table I. Showing the Chief Simple Sequences.

No. of Sequence	Initial Anæsthetic.	Terminal Anæsthetic.
1.	Nitrous Oxide.	Ether
2.	Ethyl Chloride.	,,
3.	C.E. (or A.C.E.).	,,
4.	Chloroform.	,,
5.	C.E. (or A.C. E.).	Chloroform.
6.	Ether.	,,
7.	Nitrous Oxide.	C.E. (or A.C. E.)
8.	Chloroform.	,,
9.	Nitrous Oxide.	Ethyl Chloride.

It will be seen from this table that Sequences 1, 2, 3, and 4 terminate with ether; Sequences 5 and 6 with chloroform; Sequences 7 and 8 with the C.E. (or A.C.E.) mixture; and Sequence 9 with ethyl chloride. Of the sequences terminating with ether Nos. 1 and 2 are the best for general use; but Nos. 3 and 4 may occasionally be required. It will be seen that there are only two simple sequences terminating with chloroform. The use of nitrous oxide and of ethyl chloride as immediate antecedents to chloroform has unfortunately not proved satisfactory. Of the sequences terminating with the C.E. (or A.C.E.) mixture No. 7 has not, as yet, had a sufficient trial to warrant any very definite statements concerning it, although all the cases in which the author has tried it have been remarkably satisfactory. Sequence 8 has no great advantage over the administration of the C.E. mixture *ab initio.* Although the author has endeavoured on many occasions to obtain good results with ethyl chloride as a preliminary to the C.E. (or A.C.E. mixture) the results

have not been very satisfactory. The ethyl chloride-C.E. sequence does not therefore appear in the table. Sequence 9 is useful in dental surgery. Numerous other simple sequences, in addition to those mentioned in the table, have from time to time been advocated. Thus Clover, who, as we have seen, entertained a very favourable opinion of ethidene dichloride, used to precede the administration of this anæsthetic by nitrous oxide; but this sequence has never come into general use. The ethyl bromide-ether sequence, which is employed upon the Continent,[1] is not included in the table because of the objections which, as we have seen (p. 447), are attached to ethyl bromide as an anæsthetic.

SEQUENCE 1: THE NITROUS OXIDE-ETHER ("GAS AND ETHER") SEQUENCE

We are indebted to Clover for the valuable suggestion and practice of administering nitrous oxide before ether. The former agent is a particularly appropriate one for *inducing* anæsthesia. It is by no means unpleasant to inhale; it rapidly destroys consciousness; its administration is unattended by excitement or struggling; and its use is practically free from risk to life. Although ether, as we have already seen, is the best anæsthetic for ordinary surgical work, the sensations which attend its administration *ab initio* are distinctly disagreeable. Nitrous oxide therefore supplies the very qualities in which ether is deficient. From the point of view of the patient it is a great boon to be rendered unconscious quickly and to be spared the suffocative and other feelings which attend the initial stages of etherisation. Moreover, ether is a particularly appropriate anæsthetic to administer in conjunction with or immediately after nitrous oxide, because the exclusion of atmospheric air, which is essential in the case of the latter anæsthetic, is to a certain extent advantageous in the case of the former. In other words, we may pass from deep nitrous oxide to deep ether

[1] Prof. Kocher of Berne warmly recommends this sequence. See *Lancet*, 12th Sept. 1905 (Dr. Haggard's article).

anæsthesia without admitting that quantity of air which would be essential were we dealing with chloroform.

Clover's first plan[1] for the employment of this sequence was to render the patient unconscious with nitrous oxide, and then to change the inhaler for an ether apparatus. His next method was to first administer nitrous oxide by itself, and then to gradually add ether by causing the gas to pass over this anæsthetic. After working at the subject for many years, he perfected his combined "gas-and-ether" apparatus, which is conspicuous for its ingenuity. Experience has proved, however, that this appliance is not only too cumbrous and complicated for general use, but that it possesses other disadvantages. The principal of these is that the channels through which the patient has to breathe are so constricted that considerable stress is thrown upon respiration; whilst it is difficult if not impossible to thoroughly cleanse all parts of the inhaler.

Attempts have from time to time been made to administer nitrous oxide and ether by passing the gas through a Clover's portable ether inhaler. It is not proposed to describe in detail what has been done in this direction, as no useful purpose would be served. The chief difficulty which presented itself was, that whereas for the successful administration of nitrous oxide the escape of expired "gas" was essential, at all events at the commencement of the inhalation, no such escape of the expirations was necessary in administering ether—in fact, to-and-fro breathing was advisable. Some years ago the author devoted a considerable time to this particular matter. He found that by attaching a bag containing nitrous oxide to a Clover's inhaler, and by employing a stopcock which would allow of one-half of the nitrous oxide being breathed through valves, and of the remaining half being breathed backwards and forwards during the gradual admission of ether vapour, a very satisfactory result could be obtained. With the introduction of the wide bore modification of Clover's inhaler even greater success was achieved than was possible with the narrow bore models.

The **apparatus** necessary for obtaining the best results with this sequence consists of: (*a*) a face-piece of appropriate size: (*b*) the wide

[1] *Brit. Med. Journ.*, 15th July 1876, p. 74.

bore ether chamber and bag of Fig. 41, p. 334: (c) a nitrous oxide stopcock and bag similar to that shown in Fig. 23, p. 270, but with a stopcock of larger bore: and (d) a cylinder or cylinders for the supply of nitrous oxide. The face-piece is fitted to the ether reservoir which, except in hot weather, should be immersed for a few moments in warm water. The nitrous oxide bag is partly filled with nitrous oxide (the quantity placed in the bag being a matter of importance), and the stopcock of the bag is fitted to the ether reservoir. For men with hair about the face the bag should be quite full; for very tall or strong men nearly full; for men of average height and for healthy women about three parts full; and for weakly women and children about half full. The face-piece should be so adjusted upon the ether reservoir that the open filling-tube of the latter is horizontal and ready for the reception of the ether; the ether indicator should point to "0"; and the valves of the stopcock should be dry and freely acting.

The **administration** is thus conducted. The apparatus having been accurately applied, the patient is requested to breathe backwards and forwards through the mouth. Air will enter and leave the stopcock. Nitrous oxide is then turned on, and one half of the quantity in the bag is breathed out at the expiratory valve. The valves are now thrown out of action, and to-and-fro breathing of the remainder of the gas results. After a few to-and-fro breaths, about half an ounce of ether is rapidly poured into the inhaler (Fig. 64); the plug of the filling-tube is replaced; and the rotation of the indicating handle is commenced. The juncture at which the ether is introduced is a matter of importance. The ideal moment is that at which consciousness vanishes. If it be poured in too soon, the patient may detect and remember the unpleasant odour of ether. If the introduction be unduly deferred, there is the chance that, just as the anæsthetist is engaged in pouring in the ether, the symptoms of the patient may indicate the need for the first breath of air, and as this need cannot at the moment be satisfied, the administration loses that absolute smoothness which usually characterises it. If the patient be easily affected by nitrous oxide, the ether may be poured in after two or three to-and-fro breaths. If he be comparatively insusceptible, ten or twelve of such breaths may be necessary before a sufficient degree of insensibility is produced. The rotation of the indicating handle is effected rather more rapidly than in administering ether

without nitrous oxide. It is quite exceptional for the slightest cough, breath-holding, or movement to occur. When snoring commences, one inspiration of air is allowed. Should any epileptiform twitching arise, this symptom must also be taken to indicate the need for air. The indicator is gradually made to pass towards "F," an occasional breath of air being

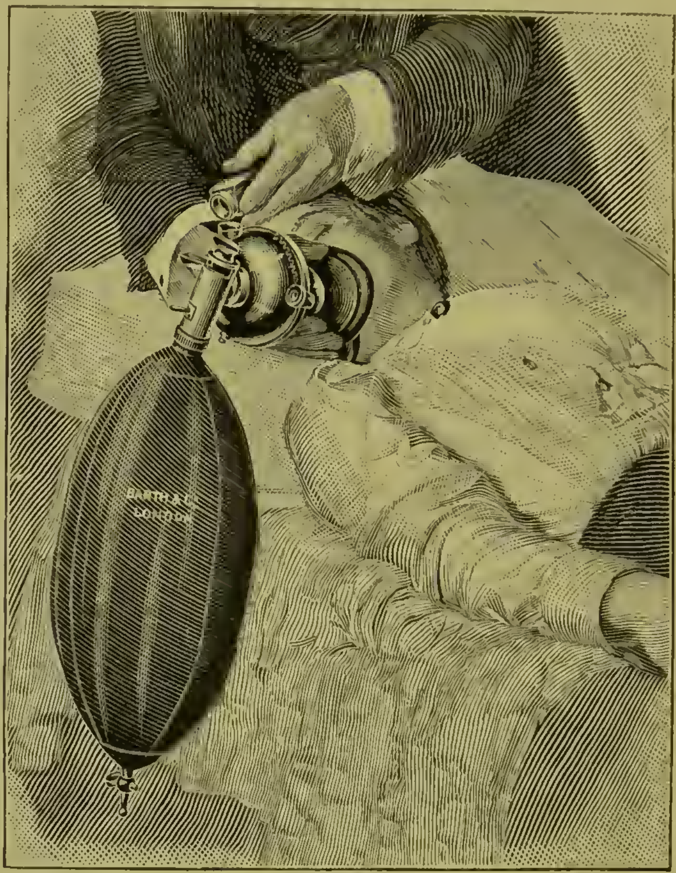


FIG. 64.—The Administration of Nitrous Oxide and Ether by means of the wide-bore modification of Clover's Ether Inhaler and the author's Nitrous Oxide Stopcock.

permitted. It is often a good plan to expedite vaporisation by grasping the ether reservoir with the hand. At the end of about one or one and a half minutes the indicating handle should be suddenly brought back to "0"; the gas-bag exchanged for the smaller ether bag; and the handle again moved onwards to "2" or "3" according to the type of subject. The apparatus then presents the appearance of that shown in Fig. 41, p. 334, and the administration is conducted as already described when discussing ether anæsthesia

(p. 335). If these details be carefully followed, the patient will not be conscious of the slightest odour of ether, and anæsthesia will be induced without excitement, struggling, or asphyxial complications. The advantage of having a large bore to the ether vessel has already been alluded to, and this advantage is very conspicuous in passing from nitrous oxide to ether anæsthesia.

This method of administering nitrous oxide and ether has numerous advantages. Firstly, it is precise; that is to say, with known quantities of the two anæsthetics, and with a perfectly fitting face-piece, one is able to obtain similar results in similar subjects. Secondly, if the quantity of nitrous oxide be carefully adjusted to the requirements of the particular case, it is possible to obtain all the advantages of this anæsthetic as an induction agent without the occurrence of asphyxial symptoms. Thirdly, only a limited quantity of nitrous oxide is needed, so that the bag may be filled before the patient enters the room. The patient is thus spared the noise, etc., connected with the supply of nitrous oxide to the bag, and the administrator is spared the trouble of keeping up a supply of the gas with the foot-key during the administration. One frequently has to give "gas and ether" to patients who are lying in bed, and under these circumstances it is a great convenience to have at hand a detached bag of nitrous oxide. As already mentioned (p. 161), the method is not very satisfactory for patients with much hair about the face, owing to the impossibility of obtaining perfect coaptation of the face-piece.

The narrow-bore Clover's inhaler shown in Fig. 35, p. 330, with the corresponding stopcock and bag of Fig. 23, p. 270, will also answer well for this sequence, but not so well as the wide-bore apparatus. The administration with a narrow-bore inhaler is represented in Fig. 65. As it is necessary with the narrow-bore inhaler to charge the ether reservoir before applying the face-piece, there may be an odour of ether when the patient commences to inhale. As already mentioned, there is a greater liability to stertor and cyanosis with a narrow-bore than with a wide-bore apparatus. With the exception that the ether chamber is charged with ether before use, the administration is conducted in the way above described.

There is a simple way of administering nitrous oxide and ether which is employed by some anæsthetists. The metal angle-piece to which the bag of Clover's inhaler is attached is furnished with a small tap to which a tube from a nitrous oxide cylinder may be fitted. The administration

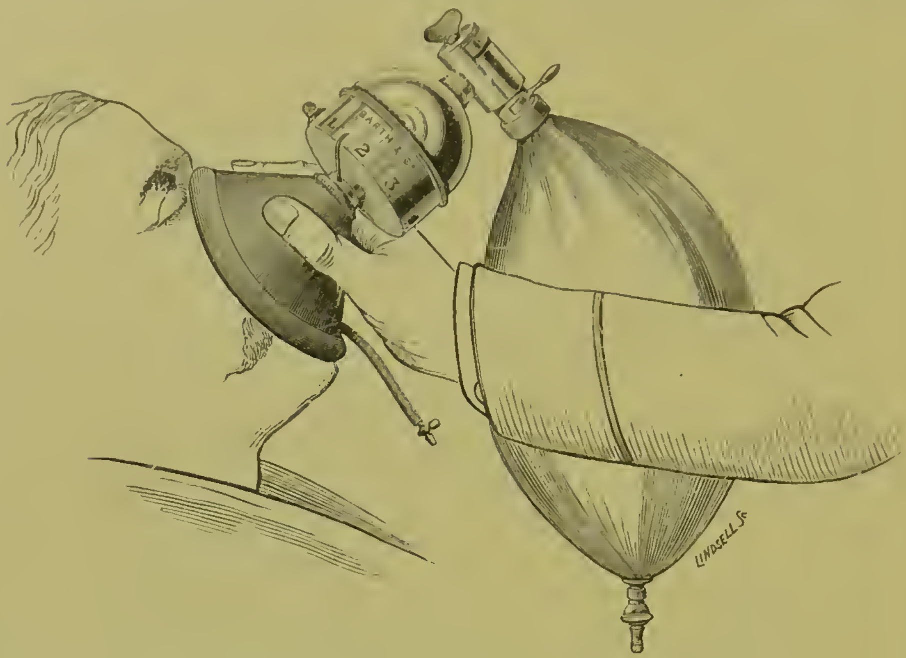


FIG. 65.—The Administration of Nitrous Oxide and Ether by means of Clover's Ether Inhaler and the author's Nitrous Oxide Stopcock.

is begun by allowing some nitrous oxide to pass into the bag, and the patient breathes this backwards and forwards whilst ether is gradually mixed with it by rotating the ether reservoir. For reasons already given, this plan is not so suitable as that just described, although it certainly has the merit of simplicity.

SEQUENCE 2: THE ETHYL CHLORIDE-ETHER SEQUENCE

This sequence is now extensively employed, although in the hands of the author it has not produced such satisfactory effects as the nitrous oxide-ether sequence. It is true that ethyl chloride rapidly destroys consciousness, and that by a little practice its anæsthesia may be made to pass into that of ether without resistance, excitement, embarrassed breathing, struggling, or cyanosis. From the patient's point of view, however, the initial sensations are somewhat less pleasant than those of nitrous oxide. As already mentioned, it is necessary to administer a fairly strong ethyl chloride vapour in order to

produce that rapid effect which is essential if we wish to eliminate excitement, and it is this strength of vapour which may constitute the disadvantage of the sequence. By a very slight error in the adjustment of the initial strength, suffocative sensations, culminating in breath-holding, struggling, and respiratory spasm, may occur. At the same time, there can be no doubt that this sequence constitutes a valuable addition to our resources.

One of the best ways of administering these anæsthetics in succession is the following. The apparatus required is that shown in Fig. 41, p. 334. Although not designed for this sequence, it happens to meet every requirement. About 3 c.c. of ethyl chloride are sprayed into the bag, which is then fitted to the ether reservoir. The ether indicator is *turned to* "*F*," the plug of the filling tube is removed, and the face-piece is applied. With this arrangement of apparatus the to-and-fro current will be found to chiefly pass through the wide and open filling tube, the thick walls of the rubber bag offering so much resistance to the current that it takes the easier course. The result of this is that little or no ethyl chloride vapour is at first breathed. As the handle is gradually moved, however, *from* "*F*" *towards* "*0*," the resistance to the current through the empty ether chamber increases, so that more of the current enters the bag. In this way the strength of the ethyl chloride vapour is gradually augmented, and when "0" is reached the breathing takes place entirely into and out of the bag. All that is now necessary is to pour in about an ounce of ether through the open filling tube, to replace the plug, and to gradually move the indicator *from* "*0*" *towards* "*F*." Should the ethyl chloride produce an unexpectedly profound effect, and abolish corneal reflex, air must be admitted during the transition. Under ordinary circumstances, however, air is unnecessary until ether stertor commences. The rotation of the indicating handle may be effected rather more rapidly than in the nitrous oxide-ether sequence. In this way ethyl chloride anæsthesia may be gradually made to pass into ether anæsthesia, and the latter condition may be maintained as already described.

If preferred, the **wide-bore inhaler** may be used somewhat differently. About 3 c.c. of ethyl chloride are placed in the ether reservoir itself, which in warm weather may require cooling before the introduction of the anæsthetic. The indicator of the inhaler is turned to "0," and the face-piece is applied so as to catch two or three expirations in the bag. After a few respirations, the indicator is gradually turned on to "1," "2," etc., as in administering ether, till deep breathing, stertor, or a dulled lid reflex indicate sufficient ethyl chloride anæsthesia. The indicator is then rapidly brought back to "0," the plug is removed, and about an ounce of ether quickly introduced. At this juncture a breath of air may possibly be necessary. The indicator is now gradually turned on, and ether anæsthesia ensues in the ordinary course, an occasional breath of air being admitted.

Another convenient plan is to use the **modified Ormsby's inhaler** of Fig. 43, p. 338. The sponge having been removed and placed near at hand, about 3 c.c. of ethyl chloride are sprayed into the bag. The inhaler, with its air-slot open, is then applied during an expiration. About an ounce of ether is now poured upon the sponge, or the latter is made to absorb this quantity of ether from an open glass vessel. By gradually closing the air-slot as already described, ethyl chloride anæsthesia is rapidly induced. The etherised sponge is then passed into the inhaler, which is quickly replaced, and ether anæsthesia then supervenes.

All the three methods just described have the advantage that there is no ether in the inhaler when the ethyl chloride is being administered. Sometimes, however, it is convenient to charge the ether inhaler with ether before inducing anæsthesia. Thus McCardie[1] employs an ordinary Clover's inhaler, with the addition of a two-way stopcock in the angle piece of the bag. A few c.c. of ethyl chloride are placed in the bag, and the stopcock is turned off, so that the vapour is imprisoned. The ether chamber is charged with ether, and the indicator turned to "0." The face-piece is applied during two deep expirations, which are caught in the bag by closing the two-way stopcock at the end of the second expiration. The patient is instructed

[1] *Birmingham Medical Review*, November 1905.

to breathe very quietly, the air-hole of the stopcock being gradually closed, so that the way is opened to the bag containing the ethyl chloride. Anæsthesia takes place so rapidly that ether vapour may be quickly admitted to the current. It is important not to use more than 2 or 3 c.c. of ethyl chloride, and to admit air when stertor commences. In this way ether anæsthesia becomes quickly induced.

SEQUENCE 3: THE C.E. (or A.C.E.)-ETHER SEQUENCE

This sequence is very useful in certain cases. Thus, when it is desired to induce ether anæsthesia without employing any closely fitting inhaler, as is not infrequently the case in nervous and breathless men or women of middle age, or when it is unadvisable or impossible to use either of the two sequences already discussed, the C.E. (or A.C.E.) mixture may with advantage be employed before ether. Again, it not infrequently happens that it is necessary to administer ether to a patient who is lying in bed, too ill, perhaps, to be moved. Under such circumstances it is clear that the simplest and least alarming method will be the most appropriate; and nothing can be simpler and less alarming than to sprinkle a chloroform mixture upon a Skinner's mask. And lastly, this sequence is very useful, as already indicated, for anæsthetising children (p. 155).

The **apparatus** which is necessary and the method which is followed will depend upon the type of subject. For strongly built, obese, or alcoholic subjects, and especially for patients of plethoric habit with short, thick necks, the following plan gives the best results. A Skinner's mask (Fig. 55, p. 384), a Rendle's mask (Fig. 34, p. 326), and an Ormsby's inhaler (Fig. 43, p. 338) are needed. The C.E. (or A.C.E.) mixture is administered from a Skinner's mask for about two minutes. The Rendle's mask, with about $\frac{1}{2}$ drachm of the mixture upon its sponge, is then gradually applied, and more of the mixture added from time to time. At the end of another minute or two, when the breathing is becoming deeper and of an unconscious type, when muttering or phonation occurs, or when slight rigidity begins to show itself in the arms, the

Ormsby's inhaler, with about ½ an ounce of ether upon its sponge, is very gradually and loosely applied. It is a remarkable fact, and one which the author has frequently had occasion to verify, that the application of a close ether inhaler at the commencement of the excitement stage of the C.E. (or A.C.E.) mixture will almost immediately cut short that stage and bring about stertor and muscular relaxation. The most probable explanation of this fact is that the application of a bag inhaler to a patient whose circulation already contains a considerable quantity of chloroform quickly intensifies the chloroform effect by the addition of the oxygen-deprivation and carbonic acid-retention factors (p. 47). Doubtless the ether factor contributes, but probably only secondarily. This particular sequence, when employed as described, is very useful for patients who are often termed "difficult" or "bad" subjects. If the apparatus described be not available, a Skinner's mask and a wide-bore Clover's inhaler will answer almost as well.

The following illustrative cases may here be quoted :—

Illustrative Case, No. 22.—M., about 35. One of the most powerful men I have ever seen. Chest measurement, 43 inches. Thick, large neck. Florid colour. A great athlete. Has lived well. Operation, radical cure of hydrocele. Duration, one hour. Administration begun at 9.50 A.M. with Skinner's mask. No holding of breath. When Rendle's mask applied there was occasional swallowing, but good respiration. Administration thus continued till breathing deeper. Changed to Ormsby charged with pure ether. More swallowing, and slight but not inconvenient movement of hand. Breath held very slightly. Some tonic spasm in neck and other parts, but no inconvenient movement. A breath of air given. Soon deeply snoring, but still a trifle rigid. At 10.20 pupils 2½ to 3 mm., the right size for this particular case ; they had been 3½ mm. Very deep stertor. Pulse 114 : very full and bounding. Respiration 28 : regular, deep, and loudly stertorous. Stertor lessened by pushing jaw forward. Less ether allowed some tendency to crowing breathing, and made pupils *larger*. When operation over, less ether made pupils smaller. Vomited half an ounce of fluid immediately after operation. No subsequent nausea.

Illustrative Case, No. 23.—Patient a little boy, æt. 2 years 3 months. Florid. Breathes through mouth. Operation 10 A.M. : no food since previous evening. Semi-recumbent position. A few drops of A.C.E. mixture at a time on Skinner's mask. Some crying, but no resistance. After 1-1½ minutes Clover's inhaler previously charged with

ether and turned to "1" applied. Anæsthesia in 2-3 minutes. Noisy regular breathing: colour rather dusky: pupils 3 mm.: no lid-reflex: quite relaxed: pulse good and full. Total length of administration, including A.C.E. mixture = 5 minutes. Mouth opened by Mason's gag, and head arranged for good light to enter mouth. Tonsils removed by guillotine. Mouth sponged. No movement. Head and body now tilted forwards, and post-nasal space cleared of adenoid growths. Blood and detached growths came away from mouth and nose without slightest embarrassment to respiration. No sponging necessary. No movement. Operation, which lasted about 3-4 minutes, now over. Head kept forwards for drainage. Some cough and movement. Child turned on his side, in which position he lay quietly breathing, and with good colour for 10 minutes. Then began to cry and move about.

When patients are so feeble that it is thought unadvisable to employ the close system of etherisation, all that is needed is a Skinner's mask for the C.E. mixture and a Rendle's mask for the ether. The two following cases will serve to illustrate the use of this sequence in such cases.

Illustrative Case, No. 24.—M., æt. about 37. Thin; feeble; right lung useless; pus coughed up daily; also purulent discharge from old empyema incision; left lung apparently healthy; temperature elevated; quick pulse. One ounce of brandy, with an equal quantity of water, given by order of the surgeon, 5 minutes before administration. A small quantity of A.C.E. mixture given for a minute or two; then ether (Robbins's pure ether) on a semi-open inhaler. No difficulty whatever. Little if any cough. Allowed a little movement occasionally. (I have omitted to note the nature of operation, but I believe a portion of rib was removed.) The patient had been anæsthetised twice before with the A.C.E. mixture, and I was informed his breathing had ceased on each occasion.

Illustrative Case, No. 25.—F., æt. about 52. Stout. Sitting up in bed. Cannot lie down. Has morbus cordis, and is subject to attacks of angina pectoris and cyanosis. Pulse very feeble and irregular at wrist. (Precise nature of cardiac affection not ascertained.) Wheezing sounds at bases of lungs. Anæsthetic required for passive movement of stiff shoulder. Commenced with a small quantity of A.C.E. mixture (two minutes' inhalation) on an open felt cone, and then gave ether on same inhaler. Very gradual administration. Respiration grew deeper. An occasional cough. Conjunctiva never insensitive, though once nearly so. Colour always good. Pulse improved when under ether. Manipulations of shoulder lasted 6 minutes. Came round gradually with moaning respiration. No cyanosis. Satisfactory recovery from effects of anæsthetic.

For **small children** requiring short operations such as that of circumcision this sequence is very useful. The mixture

may be administered whilst the little patient is lying in bed (p. 154). A Skinner's mask and a Rendle's mask of small size are required. When partial anæsthesia has been obtained by the C.E. mixture and Skinner's mask, the Rendle's inhaler with about a drachm of ether upon the sponge is gradually applied. More or less constant lip friction may be needed during the administration of the ether (pp. 328, 420, and 555).

SEQUENCE 4: THE CHLOROFORM-ETHER SEQUENCE

From some points of view chloroform would seem to be a particularly appropriate anæsthetic to administer before ether. It is not unpleasant to inhale; its exhibition requires no complicated apparatus; and a small quantity is needed to produce unconsciousness. Chloroform has, indeed, been largely used as a preliminary to ether. The results, however, are not always as satisfactory as might be expected, an inconvenient state of partial anæsthesia occasionally marking the transition from the one anæsthetic to the other. We must not lose sight of the fact, moreover, that most of the fatalities during chloroformisation have occurred early in the administration, *i.e.* before true surgical anæsthesia has been produced. From this it follows that, in using chloroform for the purpose of preventing the initial discomforts of ether, we may be subjecting the patient to greater risk than in employing ether alone. The risk will be in proportion to the extent to which we carry the inhalation of chloroform. If, as is advisable, we carry it only so far as to blunt the sensibility to the pungency of ether vapour, the additional risk will be practically *nil.* If we carry the administration beyond the second stage, the risk will be considerably increased.

For **administering** chloroform before ether the anæsthetist should be provided with a Skinner's mask and a drop-bottle for the former, and with a Clover's, Ormsby's, or Rendle's inhaler for the latter anæsthetic. If a Clover's apparatus be used, its indicator should be turned to "0" before being applied, and the strength of the vapour increased, as occasion may require, till the ordinary signs of ether anæsthesia result.

Speaking generally, we may say that the change from

chloroform to ether should be effected just before the point at which mental and muscular excitement usually commence. Should chloroform be given for a few seconds only, and the ether inhaler be then applied, the patient, though perhaps not conscious of the change of vapour, may give trouble by swallowing, suspended breathing, coughing and struggling. Should the chloroformisation be carried too far, the advantages of ether in preventing "false anæsthesia" and in stimulating the circulation will, to a great extent, have been lost. The remarks already made (p. 488) in connection with the preceding sequence, as to the sudden increase in the depth of anæsthesia which occurs when a close ether inhaler is applied to the air-passages of a patient partly under a chloroform and ether mixture, hold good in the present connection.

SEQUENCE 5: THE C.E. (or A.C.E.)-CHLOROFORM SEQUENCE

As will subsequently be seen there are certain excellent sequences of the compound variety which terminate with chloroform. These are principally suitable, however, for patients whose general condition is satisfactory. In other subjects it may be unadvisable to use these compound sequences, and under such circumstances the present sequence will answer well. For example, in bloated, obese, and emphysematous patients requiring an urgent abdominal section this succession is particularly appropriate; and numerous other instances will occur to the reader. The advantage of preceding chloroform by the C.E. or A.C.E. mixture is that the most dangerous stage in chloroformisation, *i.e.* the induction stage, is thus eliminated.

SEQUENCE 6: THE ETHER-CHLOROFORM SEQUENCE

As we shall presently see, when discussing compound sequences, the best way of obtaining the advantages of ether as an antecedent to chloroform is by employing such a sequence as the nitrous oxide-ether-chloroform sequence. When, however, such methods of anæsthetisation are impracticable, as

in busy hospital practice, and when it is desired to secure the advantages of ether for the induction period and to administer chloroform subsequently, the former anæsthetic must be given *ab initio* as described on p. 335, and a change to chloroform effected just before full ether anæsthesia has been secured. By this plan the risks incidental to chloroform will be greatly reduced. The etherisation should be carried to the point at which snoring breathing co-exists with a still sensitive but nearly insensitive cornea. It is best to have the Skinner's mask well moistened with chloroform just before the point arrives at which the change from ether to chloroform should be effected, and when the point has arrived, the inhalers should be quickly exchanged. It frequently happens when the ether apparatus is removed, that the breathing is imperfectly nasal, the result being that the chloroform vapour is not breathed as freely as is desirable. It is, therefore, a good plan either to hook back the angle of the mouth with the finger or to quickly insert a mouth prop at the same moment at which the Skinner's mask is applied. By thus securing free access for the chloroform vapour, the corneal reflex will gradually lessen and the patient will pass without difficulty into chloroform anæsthesia of a very satisfactory type. The change to chloroform must not be made soon after commencing etherisation, otherwise struggling may result; nor should it be made during struggling. It is also important not to effect the change during full ether anæsthesia; otherwise difficulties from the presence of laryngeal mucus may occur and complicate the administration. The patient should have been brought to the threshold of deep ether anæsthesia and be free from any noteworthy asphyxia when the change is made. Any tendency to coughing or swallowing, if associated with signs of deep anæsthesia, will constitute a good indication for the change to chloroform. Should the chloroform have been given prematurely, and the patient struggle, the ether inhaler must be again applied for a few moments and the struggling will at once subside. Should profound ether anæsthesia have been produced, the patient should be allowed to recover slightly and to cough or swallow before chloroform is applied. If this be not done,

laryngeal stridor, jaw-spasm, and other difficulties may be experienced throughout the chloroform administration. The author has notes of more than one case in which the presence of ether-mucus seemed to be the determining factor of respiratory arrest under chloroform, the patient at the moment being deeply, but not dangerously deeply, under the latter anæsthetic.

SEQUENCE 7: THE NITROUS OXIDE-C.E. (or A.C.E.) SEQUENCE

It has already been pointed out that the C.E. mixture is an excellent anæsthetic for a large number of cases. It has, however, certain slight drawbacks connected with the early stages of its administration. Many patients dislike the inhalation of a *vapour* even though that vapour be not unpleasant; some time necessarily elapses, particularly in healthy subjects, before this vapour, gradually administered, destroys consciousness; and in a certain proportion of cases some excitement and struggling attend the induction stage. In those patients whose general condition is unsatisfactory by reason of some serious illness, there is no known way of obviating these slight drawbacks, for in such subjects it is of paramount importance to admit air freely with the anæsthetic vapour from the very outset of the administration. In healthy subjects, however, in whom the C.E. (or A.C.E. mixture) is indicated, the author has on a considerable number of occasions preceded the administration by nitrous-oxide gas, employing the following arrangement of apparatus.

The inhaler shown in Fig. 62, p. 463, which is primarily intended for the C.E. mixture *per se*, and which, as we have seen, is also useful for ethyl chloride, is so adjusted that its air-holes are closed. A new open-meshed sponge is moistened, and carefully cut so as to loosely fit the interior of the inhaler. To the open chimney of the inhaler the charged gas-bag used in Sequence 1 (Fig. 64) is fitted. The bag should be filled with an appropriate quantity of nitrous oxide as in conducting that sequence. The apparatus will then have the appearance shown in the accompanying figure (Fig. 66). A drop-bottle of C.E. mixture, capable of supplying this anæsthetic in a small stream, is necessary.

The patient first breathes air through the air-slot of the stopcock. Nitrous oxide is then admitted. One half of the

gas escapes through valves, the remainder being breathed backwards and forwards. At about the seventh, eighth, or ninth breath, according to the effect which the nitrous oxide has produced, the little handle of the inhaler is turned so as to open one of the two small holes in the circumference of the inhaler. A small quantity of the C.E. mixture is quickly poured through this hole on to the sponge, some air necessarily and designedly entering during the process. *The conjunctival reflex must be carefully watched.* Breathing now takes place partly into and out of the bag and partly through the air-hole. After about half to one minute of this kind of breathing the bag and stopcock are detached and the inhaler turned into the position shown in Fig. 63, p. 463, fresh C.E. mixture being added as there indicated.

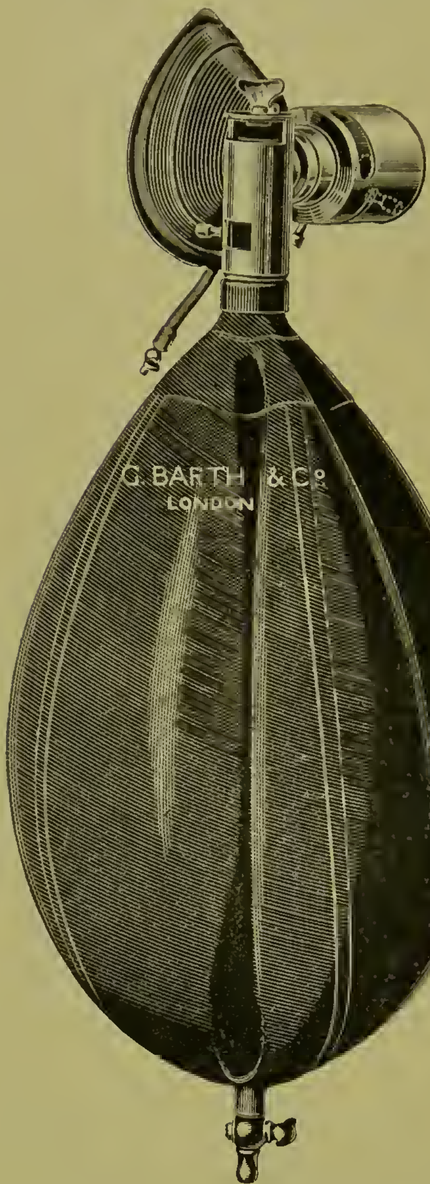


Fig. 66.—Arrangement of Apparatus for the Nitrous Oxide-C.E. Sequence.

Up to the time of writing [October 1906] the only patients whom the author has anæsthetised by this method have been with one or two exceptions the best subjects for anæsthetics, *i.e.* young or middle-aged women in good condition. The results, however, have been so uniformly satisfactory that he ventures to describe the method in the hope that others may find it worthy of trial. In no case has there been any excitement or struggling. Whether the plan will prove to be of use for muscular men and other somewhat difficult subjects future experience must decide.

SEQUENCE 8: THE CHLOROFORM-C.E. (or A.C.E.) SEQUENCE

This sequence is useful when the patient particularly desires chloroform, at all events for the commencement of the administration, whilst other indications point to the use of the C.E. (or A.C.E.) mixture. The change to the C.E. mixture may be effected at the end of one and a half or two minutes. In children and very feeble subjects, the mixture may be administered upon the mask which has been used for chloroform. In ordinary adult patients it will be necessary after having used the Skinner's mask, first for chloroform and then for the mixture, to substitute for it some semi-open inhaler (see p. 462).

SEQUENCE 9: THE NITROUS OXIDE-ETHYL CHLORIDE SEQUENCE[1]

The advantages of this sequence which is only applicable for brief operations, such as those of dentistry, are as follows:—The induction period is invariably smooth; the patient detects no odour of ethyl chloride; and a deep anæsthesia with muscular relaxation is obtained. A two-gallon bag is partly or completely filled with nitrous oxide according to the type of patient; a graduated tube containing about 3 c.c. of ethyl chloride is fitted to the vulcanite stopcock at the bottom of the bag; one half of the nitrous oxide is exhaled through valves; the other half is breathed backwards and forwards; the ethyl chloride is gradually tilted into the bag (Fig. 67); and a breath of air is admitted if required. The interesting point about this method is that patients are by its use plunged, in an extraordinarily short space of time, into the deepest anæsthesia with which we are acquainted, the pupils becoming dilated and the muscular system relaxed with almost alarming rapidity.

Dr. A. Moritz employed this method at the Royal Dental Hospital of London in over 3000 cases. He found that patients preferred the induction sensation to those of ethyl chloride alone; that coughing, cyanosis, excitement, and struggling never occurred during the induction stage; that marked vaso-dilatation was often produced; that deep anæsthesia

[1] This sequence was described by the author in the *Journal of the British Dental Association*. September 1903, vol. xxiv. p. 615.

came about with extraordinary rapidity; that the best results were obtained with fairly large doses (5 c.c.) of ethyl chloride without much rebreathing; that during the recovery stage there was often a long analgesia period free from movement, which could generally be utilised by the operator; that headache, vertigo, hysterical outbursts, and (in

FIG. 67.—Apparatus for the administration of Nitrous Oxide in conjunction with Ethyl Chloride.

men) pugnacious demonstrations occasionally manifested themselves after the administration; that nausea or vomiting occurred afterwards in about one case in every seven; that in alcoholic and neurotic subjects a much better result was often obtained than with nitrous oxide; that the average available anæsthesia was about 60 seconds; that the method could always be depended upon for providing an adequate anæsthesia; and that in no case were there any dangerous symptoms.

The author does not employ this method to any great extent; the percentage of cases displaying unpleasant after-effects being too high.

(B) COMPOUND SEQUENCES

These have been already defined (p. 477). They all have this in common: they terminate either with chloroform or with the C.E. (or A.C.E.) mixture. We have already seen that there is no very satisfactory simple sequence terminating with chloroform; but when we come to the compound sequences we find at our disposal at least one or two of these by which it is possible to proceed to deep chloroform anæsthesia with safety and smoothness.

The following table shows the chief compound sequences:—

Table II. Showing the Chief Compound Sequences.

No. of Sequence.	Initial Anæsthetic.	Transitional Anæsthetic.	Terminal Anæsthetic.
10.	Nitrous oxide	-ether.	Chloroform.
11.	Ethyl chloride	-ether.	,,
12.	C.E. (or A.C.E.)	-ether.	,,
13.	Chloroform	-ether.	,,
14.	Nitrous oxide	-C.E. (or A.C.E.).	,,
15.	Chloroform	-C.E. (or A.C.E.).	,,
16.	Nitrous oxide	-ether.	C.E. (or A.C.E.).
17.	Ethyl chloride	-ether.	,,
18.	C.E. (or A.C.E.)	-ether.	,,
19.	Chloroform	-ether.	,,

Sequences 10 to 15 inclusive lead up to and terminate with chloroform; sequences 16 to 19 inclusive lead up to and terminate with the C.E. (or A.C.E.) mixture.

SEQUENCE 10: THE NITROUS OXIDE-ETHER-CHLOROFORM SEQUENCE

This sequence deserves special attention. By its employment for the great majority of ordinary surgical cases, nearly every possible requirement, not only of the anæsthetist but of the patient and surgeon, may be fulfilled. As a general rule the patient who is thus treated suffers no discomfort whatever during the induction period; he loses consciousness in six or

seven breaths; there is no odour of ether either beforehand or during the transition from nitrous oxide to that anæsthetic; there is no struggling, excitement, coughing, retching, cyanosis, or respiratory embarrassment; and chloroform anæsthesia is brought about without any of those difficulties incidental to the administration of this agent *ab initio*. In addition to these great advantages the parts under operation are less vascular than when ether is employed throughout; whilst the patient is saved the unpleasant taste and other after-effects incidental to etherisation. It would, of course, be idle to assert that a smooth induction may be relied upon in every case; but provided the proper subjects be chosen, and the method be conducted with the closest attention to detail, difficulties rarely, if ever, arise. The author has now employed this succession of anæsthetics for several years, and whilst admitting that it is hardly suitable for those who have had but little experience, he can confidently recommend it to all others. By its use one is able to pass to deep chloroform anæsthesia in a comparatively short time—usually in from three to four minutes—and the somewhat disconcerting phenomenon of false chloroform anæsthesia is never witnessed.

In order that the reader may fully understand the practical details of this sequence, he should carefully study what has already been said concerning the nitrous oxide-ether and the ether-chloroform sequences (pp. 479 and 491). The nitrous oxide - ether sequence is carried to a particular point; and at this point the change to chloroform is effected. The point in question is recognised either by (1) the association of snoring breathing with corneal sensibility, or by (2) the association of a cough with corneal insensibility. As the success of the sequence under consideration largely depends upon the change to chloroform being made at the proper moment, it is particularly important that the remarks made in connection with the ether-chloroform sequence should be carefully studied.

SEQUENCES 11, 12, AND 13: THE ETHYL CHLORIDE-ETHER-CHLOROFORM, THE C.E. (or A.C.E.)-ETHER-CHLOROFORM, AND THE CHLOROFORM-ETHER-CHLOROFORM SEQUENCES

These three sequences are developments or extensions of the simple sequences Nos. 2, 3, and 4 (*vide* Table I.), the ether of which is replaced by chloroform at the juncture already fully discussed in the ether-chloroform sequence (p. 491). Sequences 11, 12, and 13 possess advantages in certain cases, but they are open to the objection that they do not so satisfactorily prevent excitement and struggling[1] as sequence 10.

SEQUENCE 14: THE NITROUS OXIDE-C.E. (or A.C.E.)-CHLOROFORM SEQUENCE

The author has employed this sequence, and with very good results, in several throat operations. Further experience is necessary before its true position can be defined. (See remarks on Sequence 7.)

SEQUENCE 15: THE CHLOROFORM-C.E. (or A.C.E.)-CHLOROFORM SEQUENCE

The advantages of administering a chloroform and ether mixture rather than chloroform itself during the second stage of anæsthetisation have already been frequently referred to. In a large number of cases in which chloroform is indicated, this sequence may advantageously be chosen. For ordinary adult subjects the following plan is adopted. Chloroform is administered upon a Skinner's mask for about one or one and a half minutes, *i.e.* till consciousness has been destroyed; the C.E. (or A.C.E.) mixture is then substituted, the same mask being used; at the end of about another one or two minutes a

[1] Mr. F. T. Paul of Liverpool (*Lancet*, vol. i., 1898, p. 679) states that it is his practice during chloroformisation to give a full dose of ether just before the stage of rigidity, and to subsequently resume the chloroform—in other words, he employs the chloroform-ether-chloroform sequence—the results being very satisfactory.

semi-open inhaler, with C.E. (or A.C.E.) mixture within it, is substituted for the Skinner's mask; and just as the cornea is losing its sensibility the Skinner's mask with chloroform is again applied. For children and feeble subjects, a Skinner's mask will suffice throughout.

SEQUENCES 16, 17, 18, and 19: THE NITROUS OXIDE-ETHER-C.E. (or A.C.E.), THE ETHYL CHLORIDE-ETHER-C.E. (or A.C.E.), THE C.E. (or A.C.E.)-ETHER-C.E. (or A.C.E.), AND THE CHLOROFORM-ETHER-C.E. (or A.C.E.) SEQUENCES

Like sequences Nos. 10, 11, 12, and 13, these sequences are extensions of the simple sequences Nos. 1, 2, 3, and 4, the only difference being that they lead up to and terminate with the C.E. (or A.C.E.) mixture instead of chloroform. Sequence No. 16 is often useful in abdominal operations; and the author has found sequence No. 18 also of value in this branch of surgery, particularly in the case of children.

CHAPTER XVI

THE USE OF MORPHINE IN CONJUNCTION WITH GENERAL ANÆSTHETICS

In 1861 a case was reported by Pitha in which he succeeded in deeply anæsthetising a patient by the combined action of belladonna and chloroform, after chloroform itself had proved ineffectual. In 1863 Nussbaum[1] of Munich employed morphine in conjunction with chloroform, by injecting it *during* chloroform anæsthesia. He used from ·03 to ·06 grm. of the acetate of morphine, and found that patients thus treated remained in a deep sleep for a considerable time after the withdrawal of the chloroform, and then woke without nausea or vomiting. At about the same time Claude Bernard observed similar effects in dogs; and in 1869[2] published his researches.

MM. Labbé and Guyon[3] seem to have been the first to administer morphine *before* chloroform in surgical practice. They adopted this plan, not with Nussbaum's original object, viz. that of lessening the after-pain of operations, but with Claude Bernard's idea, viz. that of facilitating the action of chloroform, and rendering smaller quantities of the anæsthetic necessary. They injected morphine about 20 minutes before chloroform was given, and found that by this practice the excitement stage of chloroformisation was very considerably lessened, and that when once anæsthesia had been produced, extremely small doses of the

[1] The *Bavarian Med. Intelligencer* for October 1863 is stated to contain Nussbaum's paper. See also Kappeler, *op. cit.*; *Med. Times and Gaz.*, vol. i., 1864, pp. 259 and 596; *Med. Times and Gaz.*, vol. i., 1872, p. 350.

[2] *Lancet*, vol. ii., 1869, p. 789.

[3] *Med. Times and Gaz.*, 23rd March 1872, p. 359.

anæsthetic were needed to maintain insensibility to pain. In the same year Demarquay[1] drew attention to the special dangers which might arise from the combined action of the two drugs, and considered morphine contra-indicated, more especially in weak subjects. In 1877 Thiersch[2] employed the method in several operations about the mouth, and found it possible to maintain an analgesic state in which the patient, although unable to feel pain, could aid the operator by coughing out blood, etc., when requested to do so. Within more recent times other surgeons have advocated this preliminary injection of morphine. Thus, Dr. Alexander Crombie of the Bengal Army, writing in 1880,[3] stated that he had then employed it in 600 cases with excellent results. He advocated the injection of one-sixth of a grain immediately after the beginning of the administration of chloroform, and found that there was less vomiting than after chloroform alone, and that there was a striking absence of all asphyxial symptoms during the chloroformisation. Kappeler has devoted much attention to the subject, and by comparing the effects of chloroform without morphine and chloroform with morphine, in the same patient, on different occasions, concludes that the mixed anæsthesia is quieter, that the excitement stage is much shortened, that the patient is brought with less muscular action into the stage of "tolerance," that irregularities in breathing, leading to asphyxial symptoms, are conspicuously absent, and that much less chloroform is required. He finds, however, that vomiting is more frequent than after chloroform alone. Kappeler prefers to inject morphine 20 to 30 minutes before the chloroform is given, and uses in adults ·015 grm., and in children ·01 grm.

The use of morphine before chloroform has been found to be advantageous in cerebral surgery,[4] there being less vascularity of the brain and its membranes with this "mixed narcosis" than with chloroform alone. As many of the patients requiring these operations, however, may be at the time of the administration in a state of torpor or semi-coma, or may

[1] *Med. Times and Gaz.*, 21st September 1872, p. 334.
[2] *Lancet*, 8th December 1877, p. 861.
[3] *Practitioner*, December 1880, p. 401.
[4] *Brit. Med. Journ.*, vol. ii., 1886, p. 670. See also p. 218 of present work.

during the operation display symptoms of shock or respiratory depression, considerable discretion must be exercised in applying the method. Many surgeons, indeed, who at one time used this mixed narcosis, have now abandoned it in these operations.

Dr. Julliard of Geneva[1] advises the injection of one-sixth of a grain of morphine 20 minutes before ether is given. He very properly insists that a preliminary trial of morphine some days before the operation should be made, in order to ascertain the patient's susceptibility to the drug. Dr. Julliard finds that patients are more quietly etherised after morphine than under ordinary circumstances. He also uses far less ether to keep up anæsthesia, and indeed in many cases is able to secure an analgesic effect. Curiously enough, Kappeler states that he met with many failures in giving ether after morphine, and with more excitement than usual.

Dastre, Morat,[2] and Schäfer[3] have advocated the addition of atropine to morphine with the object of avoiding cardiac inhibition during anæsthesia, the atropine being given in doses of from $\frac{1}{100}$th to $\frac{1}{120}$th of a grain. As is pointed out elsewhere, there is good evidence to show that the risk of cardiac inhibition during anæsthesia is far less than was formerly supposed, so that there is little or no need for any such precautions.

The use of morphine in conjunction with general anæsthetics has, in the author's hands, proved to be of most service in cases in which, for some reason or another, it would otherwise have been difficult to secure the desired degree of muscular relaxation and quietude. In the following cases the modifying influences brought about by the morphine will be sufficiently obvious:—

Illustrative Case, No. 26.—F., about 32. A cripple. Often has morphia for pain. Short and thin: rather anæmic: has been losing blood. Good heart-sounds and chest expansion. Quick pulse. Oöphorectomy lasting $1\frac{1}{4}$ hour. "Gas and ether" by Braine's method. Put fairly well under "gas," but not as far as deep stertor. Considerable

[1] *Op. cit.* See also *Brit. Med. Journ.*, vol. i., 1891, p. 920.
[2] See Dastre, *op. cit.*
[3] *Brit. Med. Journ.*, 16th October 1880, p. 620. Also *Brit. Med. Journ.*, vol. ii., 1880, p. 240.

struggling during change to ether. (No remembrance of this on recovery.) Some delay in obtaining deep anæsthesia. Next day abdomen reopened. Temperature rising. Quick pulse. Precisely same plan of administration; but three doses of morphine (each $\frac{1}{6}$ grain) had been given between first and second operations. Pupils small. Says feels drowsy. Skin moist. "Gas" given to same degree as before. Respiration became quieter than usual. *Change to ether not accompanied by slightest struggle or alteration in breathing.* Kept corneal reflex present. Pulse usually 180-200. Operation $\frac{3}{4}$ hour. Very little ether needed. No attempt at coughing or retching. No secretion of mucus as on previous occasion. Respiration quiet.

Illustrative Case, No. 27.—F., 18. Acute peritonitis. Temperature 102°. Ill four days. ? Suppurating tube. Has been having half a grain of opium every three or four hours. Last dose two hours before operation. Florid-looking. Quick respiration. Nervous. A.C.E. (Skinner's mask and Rendle's). Soon breathing became slower and muscles flaccid. No resistance. Conjunctiva soon insensitive. Pupils contracted. Kept a slight conjunctival reflex. No vomiting or retching. No reflex of any sort. Regular breathing. Abdomen opened and offensive pus let out. No stridor. No movement or noise. Perfect anæsthesia. Good pulse and colour. Vomited slightly 10 minutes after she had been put back to bed.

Illustrative Case, No. 28.—M., above 25. A florid, athletic man. Tall. No hair on face. One-sixth of a grain of morphine 10 minutes before administration. Operation on septum nasi and turbinated bodies. Sitting posture. Gas-ether-chloroform sequence. No struggling. Slight rigidity. No difficulty. Kept slight corneal reflex as a rule. On one occasion his arm moved, and on two occasions his neck was slightly rigid. Laryngeal and pharyngeal reflexes preserved. Hæmorrhage free on two occasions, but distinctly less than usual, considering type of subject and nature of operation. No phonated sounds. Very good result. Pulse full and slow. Respiration deep and regular. Operation lasted 50 minutes. Left patient snoring in bed. No vomiting or retching throughout.

Illustrative Case, No. 29.—F., 62. Abdominal section for (?) gall-stones. Chloroform. When well under, so much laryngeal closure and consequent embarrassment of breathing that intra-abdominal manipulations were hardly possible. One-quarter of a grain of morphine injected, and in 10-12 minutes condition improved. Deep chloroform anæsthesia needed, however, for rest of operation, which lasted $2\frac{1}{2}$ hours. No respiratory depression. Good recovery.

Illustrative Case, No. 30.—F., about 55. Thin. Not nervous. No cough. Good heart-sounds. Operation upon gall bladder. Nitrous oxide-ether-chloroform sequence at 8.35 A.M. Chloroform replaced by C.E. about 5 minutes after administration begun. C.E. for 10 minutes. Abdomen very rigid. Changed to ether. Sand-bag placed under thorax. Abdomen very rigid. At 9 A.M. $\frac{1}{4}$ grain morphine injected. At 9.10 some improvement. At 9.20 much improvement. At 9.30 breathing less "straining" in type and abdomen soft. Breathing gradually

became slower and pupils contracted. At 9.50 breathing 13 per minute. At 10.10 operation over. Very little anæsthetic required for last 15 minutes. Very good pulse. . The corneal reflex was kept in abeyance most of time. At 10.20 corneal reflex brisk.

Subsequent note.—There were no after-effects of any kind. The patient slept all day. She had no pain and no vomiting.

Illustrative Case, No. 31.—M., about 46. A powerfully built man. Have given him chloroform on two previous occasions; once for removal of half of larynx, and once for removal of further portion. On last occasion no tracheotomy tube used; lint much in operator's way; and somewhat troublesome cough throughout. To-day $\frac{1}{4}$ grain morphine 12 minutes before chloroform. Operation, suturing pharynx. In 3-4 minutes after administration begun, some rigidity of neck with half-open lids and distinct corneal reflex. Less struggling and rigidity than on former occasion. Found it possible to keep up anæsthesia by pumping chloroform vapour by means of Junker's inhaler *over* site of operation—a plan which would have been quite useless in the absence of morphine. Operation $1\frac{1}{2}$ hour. Only coughed three times, and then not inconveniently. Great improvement in type of anæsthesia. Hands moved slightly once or twice, but not inconveniently. Respiration tranquil. Colour good. Pulse good. Very little hæmorrhage. Patient in dorsal posture with head extended. In this delicate operation great quietude was essential, and this could not have been secured (in such a subject during such an operation) by chloroform alone.

Whilst there can be no doubt that the use of morphine in conjunction with general anæsthetics is of distinct advantage in many cases, we must not lose sight of the fact that objections to the routine employment of this mixed narcosis undoubtedly exist. In addition to Demarquay, others have raised a warning voice as to the danger of employing opiates in conjunction with anæsthetics in certain cases. Dr. E. H. Jacob[1] of Leeds points out that there may be some risk in administering ether to patients already under the influence of an opiate, and cautions surgeons to be on the alert for this contingency when operating for hernia, as patients with that affection are often under opium at the time the anæsthetic is given. Mr. Clement Lucas[2] states that he has seen two cases of collapse and death after operations for hernia, and believes that the morphine was to a great extent answerable. These views are quite in accordance with those which the author ventured to express in 1886. When writing in that year he was unaware that any attention had previously been directed to

[1] *Brit. Med. Journ.*, vol. i., 1881, p. 30. [2] *Ibid.* vol. i., 1882, p. 500.

the dangers of the mixed narcosis. He then published [1] details of a case in which, during the operation for the removal of a cerebral tumour, the patient being at the time under the combined influence of morphine and chloroform, respiratory paralysis took place. The case possessed so many points of interest that it may be again related.

Illustrative Case, No. 32.—M. K., a female patient, æt. 26, was admitted into hospital suffering from symptoms undoubtedly due to the presence of a cerebral tumour. The day before the operation she could not be roused; her pupils were large, active to light, and equal; her pulse was 84; her respiration 18, and shallow; and she had right hemiplegia involving the face. On the day of operation she was quite unconscious; her respiration was 24, and somewhat noisy; and her pulse 100. One-third of a grain of morphine was injected subcutaneously, and the administration of chloroform (diluted with one-fifth of ethylic alcohol) was commenced by means of Junker's inhaler. Slight coughing and feeble struggling were noted. Corneæ insensitive in about four minutes. Once only after this was it necessary to reapply the chloroform for a few seconds. One drachm of the anæsthetic was required altogether. When operation commenced pulse regular but weak, and respiration shallow. Forty minutes after the administration was begun, breathing gradually ceased. Artificial respiration twice restored breathing for a short time. One hour after administration commenced, breathing ceased for third time, and could not be re-established. *Artificial respiration by Silvester's method was kept up continuously for four hours.* When artificial respiration was suspended, cyanosis ensued, and the pulse became feebler. About 2½ hours after administration commenced it was decided to attempt to complete the operation. This was successfully accomplished, artificial respiration being carried on the whole time. At the end of four hours automatic breathing returned, and the patient was moved off to bed.

It is difficult to say what was the actual cause of the cessation of breathing in this case. Whilst the anæsthetic may have been the exciting cause, it is obvious from the fact that artificial respiration had to be kept up for four hours before automatic breathing returned, that other more potent influences were at work, and amongst these the morphine probably held a prominent position.[2]

Since the case above related, the author has seen others

[1] *Practitioner*, vol. xxxix., 1887, p. 93.

[2] See also an interesting case in the *Dental Cosmos*, November 1895, p. 937. Nitrous oxide was given after ⅔ grain of morphine, and respiratory paralysis ensued. Artificial respiration was successful.

in which the use of an opiate before the administration of an anæsthetic has led to peculiar symptoms during anæsthesia. It is often possible, indeed, to tell from the manner in which the patient behaves under chloroform or ether that he has been taking morphine in some form or other. He passes with remarkably small quantities of the anæsthetic, and without any muscular spasm, into deep anæsthesia; his pupils are small; his breathing is often abnormally slow; and unless very small quantities of the anæsthetic be used, respiration may become unexpectedly impaired. Surgeons do not always acquaint the administrator with the previous treatment their patients have received, and the anæsthetist should therefore be on his guard. In feeble and exhausted patients, in those who are lethargic or semi-comatose, and in those with any respiratory difficulty, the author is of opinion that the advantages obtainable from morphine are not sufficiently weighty to counterbalance the risks attendant upon its employment.

In the two following cases, which appear to be worthy of brief notice, the state of the patient *after* the operation seemed to be due to the effects of morphine given whilst the patient was still under the influence of the anæsthetic.

Illustrative Case, No. 33.—F., about 38. Peritonitis and intestinal obstruction of four days' standing. Abdomen much distended. Frequent vomiting. Rapid respiration, entirely thoracic. A.C.E. mixture given. Abdominal section. Operation lasted about an hour. Good colour at end of operation, and fair pulse. No tracheal râles. Twenty minutes later 40 minims of Tr. opii given by rectum. In 45 minutes patient cyanosed, and in great respiratory distress. Cheyne-Stokes breathing.[1] Patient propped up in bed. Breathing gradually became calmer, and in about two hours the duskiness had passed off.

Illustrative Case, No. 34.—M., æt. 19. Fair state of health. Removal of vermiform appendix. A.C.E. mixture given throughout, except for 15 minutes in middle of administration, when chloroform was used at the request of the surgeon. Duration of administration one hour and a half. Satisfactory anæsthesia. Respiration always quick. Pulse good. At end of operation ½ grain of morphine introduced into rectum: patient still well under anæsthetic. Swallowing movements came on,

[1] See "The Influence of Certain Drugs on Cheyne-Stokes Respiration," by G. A. Gibson, M.A. (*Practitioner*, vol. xxxviii., 1887, p. 85). See also "Two Cases showing Cheyne-Stokes Respiration in connection with the Administration of Chloroform and Morphine," by L. A. Parry, M.B. (*Lancet*, 18th January 1896, p. 161).

but no cough or attempt at vomiting. Respiration became extremely quiet. Could not rouse patient. Pupils moderately contracted. Colour began to grow dusky, but duskiness kept in check by flicking chest with towel and so stimulating respiration. Pulse rather feeble. He lay like this for 45 minutes, with no cough, although some mucus could be heard at back of throat. Some moaning and restlessness. Symptoms gradually subsided, and case did very well.

In the two last-mentioned cases the author has every reason to believe that the opiate was the cause of the peculiar symptoms observed; for he has not met with such symptoms after anæsthetics when no opiate has been given.

Several fatalities have been recorded in which the fatal symptoms seemed partly if not wholly attributable to the opiate used in conjunction with the anæsthetic.[1]

Should it be decided to administer morphine before chloroform or ether, the susceptibility of the patient to the drug should be previously ascertained. One-quarter of a grain is generally sufficient, but larger doses will be needed for patients accustomed to the drug. The injection is best made about 20 minutes beforehand. The anæsthetic should be given till the usual signs of anæsthesia commence to appear. The administrator must then proceed cautiously, in case the morphine should have produced a more profound effect than has been anticipated. In a considerable number of cases it will be found to be unnecessary to abolish the corneal reflex. There are, however, some subjects in whom reflex movements will occur unless a deep degree of chloroform anæsthesia be secured. Such reflex activity is particularly liable to be in evidence in operations which involve distension of the bladder.

The objections which usually attend upon imperfectly established anæsthesia do not apply with anything like their usual force when morphine has produced its specific effect.

When it is decided to employ morphine *during* an operation—and this course is often attended by good results, as Illustrative Cases Nos. 29 and 30 demonstrate—a dose of about gr. $\frac{1}{4}$ should be given.

In administering an opiate, either subcutaneously or by the rectum, after the withdrawal of the anæsthetic, it is advisable

[1] See *Med. Times and Gaz.*, vol. i., 1867, p. 633; *Brit. Med. Journ.*, vol. i., 1881, p. 69 (several cases quoted), and vol. i., 1882, p. 501.

to wait till the patient displays distinct signs of recovery. Should much mucus be present within the air-passages, morphine should be withheld till the mucus has either been coughed out or swallowed. It is needless to add that when any pre-existing respiratory affection is present, opiates should not be given.

PART IV

THE MANAGEMENT AND TREATMENT OF THE DIFFICULTIES, ACCIDENTS, AND DANGERS OF GENERAL SURGICAL ANÆSTHESIA

CHAPTER XVII

MINOR DIFFICULTIES

In preceding parts of this work frequent reference has been made to the various difficulties and dangerous conditions with which the anæsthetist may have to deal. It has been pointed out that certain subjects are more liable to give trouble than others (Chap. VI.); that when some operations are in progress there is a special tendency to the supervention of threatening symptoms (Chap. VII.); and that each anæsthetic is capable of producing its own special states of difficulty and danger (Part III.). But whilst the circumstances which may contribute to the establishment of the abnormalities and accidents of anæsthesia are of the most varied description, the abnormalities and accidents themselves fortunately admit of comparatively simple classification. For purposes of description it is proposed first to consider, in the present chapter, the minor difficulties of anæsthetisation, reserving the consideration of the more grave respiratory and circulatory derangements for Chaps. XVIII. and XIX. respectively.

Whilst it would perhaps be misleading to emphasise the frequency with which troublesome cases present themselves in actual practice, it would be equally misleading were we to regard these minor difficulties as unimportant. By the careful observation of the patient's symptoms; by watching with an attentive eye for the slightest deviation from what may be called the normal course; and by correcting or relieving symptoms which are in themselves but trifling, it is often possible to avert respiratory arrest on the one hand or circulatory failure on the other.

Hesitating Breathing.—Patients sometimes give trouble

by breathing in a hesitating and imperfect manner. Others hold their breath and refuse to breathe at all. Difficulties of this kind are not unfrequently dependent upon respiration taking place, perhaps inadequately, through the nose. Patients should be instructed to breathe through the mouth. With nitrous oxide, restricted breathing may come about from faultiness in the inhaling apparatus, *e.g.* badly working valves, from tight-lacing, from the patient being ignorant of the manner in which he should inhale, or from sheer nervousness and apprehension. The remedy in each case is sufficiently obvious. With other anæsthetics restricted breathing is often due to too strong a vapour; but even though a very dilute vapour be used, some patients will absolutely refuse to breathe freely. In such cases encouragement and reassurance should be brought to bear; and, above all things, the administrator should never lose patience.

In some patients the breathing may remain hesitating and restricted after consciousness has been completely abolished. The author has notes of two cases in which actual cessation of respiration seemed to arise in this way. In one of these the patient was a hysterical young woman to whom nitrous oxide was being given; in the other A.C.E. was the anæsthetic, and the patient, a middle-aged man, who had obstinately refused to breathe, became so much asphyxiated that it was necessary to open his mouth and separate his tongue from the pharyngeal wall.

Crying: Sobbing.—The management of crying children has already been considered (p. 153). Crying must be carefully treated because of the liability to the intake of large quantities of anæsthetic. In administering pure nitrous oxide to a crying child it is very easy to induce an undesirable degree of asphyxia.

Early Coughing, Retching, and Vomiting.—Sometimes the contact of an anæsthetic, gas or vapour, with the mucous membrane of the upper air-passages will immediately excite coughing, retching, or vomiting.[1] This is not uncommon in

[1] The author has known a perfectly healthy individual, who had just taken food, and who wished to try the effects of the A.C.E. mixture experimentally, to be suddenly seized with emesis after one or two inhalations.

heavy smokers with irritable throats. When using chloroform, or a chloroform mixture, the retching will usually subside if the patient be engaged in conversation during the first minute or so of induction. Should this not succeed, a change from the dorsal to the lateral posture may prove successful. Similar difficulties may occur in dental practice when the mouth-prop is inserted; but they may generally be overcome by requesting the patient to mentally count his respirations. Should this not answer, a gargle of weak carbolic lotion (about 1 in 100) will probably subdue the irritability. Should retching be excited by chloroform or a chloroform mixture, the substitution of nitrous oxide as part of a sequence will sometimes prove advantageous.

Mental and Muscular Excitement: Struggling.—Amongst the common causes of excitement and struggling may be mentioned: the employment of an inhaler whose air-way is or has become restricted; undue vapour concentration; too rapid an administration; and handling or unnecessarily interfering with the patient whilst semi-conscious.

The excitement and intoxication phenomena which occasionally occur during incipient anæsthesia are important for two reasons. In the first place, the deep and irregular breathing which is often associated with them may, under certain circumstances, lead to the intake of dangerous quantities of the anæsthetic. In the second place, the muscular spasm which is so prominent a feature of these phenomena may introduce an asphyxial factor into the anæsthesia. When suitable methods are chosen and properly applied, excitement and struggling are exceptional. There are, however, certain subjects in whom difficulties from this quarter will arise, even though every care be taken. Shouting, gesticulation, pugilistic movements, and muscular spasm of various parts are most common in vigorous men, and particularly in those who have become addicted to alcohol, tobacco, and sedative drugs. When anæsthetising such patients the administrator must be on his guard, and have assistance within easy call in case the patient became unmanageable. It is very common for middle-aged or elderly men who are being anæsthetised by chloroform, or a chloroform mixture, to slowly raise the hands and subconsciously grasp

the inhaler; and if this movement, which generally subsides of itself, be roughly suppressed, violent struggling may ensue. Should the patient's movements be such that he may possibly do himself damage, or greatly interfere with the administration, they must, of course, be gently restrained by an assistant, care being taken not to lean heavily upon the chest or abdomen. As a general rule, the cautious but continuous application of the anæsthetic quickly causes mental and muscular excitement to subside. With chloroform, the air-supply should be as free as possible during so-called struggling; whereas with ether moderate air-limitation is advantageous and free from risk in patients whose general condition is satisfactory. It is not uncommon when chloroform or a chloroform mixture is being administered to a muscular or obese man for the head and shoulders to gradually become raised from the bed or table as the result of muscular spasm. With this upward and forward movement, which should not be altogether prevented, there is nearly always some temporary suspension of breathing, which, by passing the fingers through the lips, or rubbing the latter briskly with a towel, generally quickly subsides. The best way, however, to meet this difficulty, which in certain subjects should be avoided, is to apply a close ether inhaler, as already described (p. 488), for a few breaths, when muscular relaxation will quickly occur.

There are certain highly exceptional subjects in whom anæsthetics produce a delirious or maniacal state, either during incipient anæsthesia or during the recovery period. When such a state arises in connection with the induction stages it may, in the absence of sufficient assistance, render a satisfactory anæsthesia impracticable. The author has met with a few cases of this kind in dental practice,[1] whilst employing nitrous oxide and oxygen; but they also occur under other anæsthetics. In the following illustrative case, which is unique in the author's experience, the violent excitement came on under nitrous oxide preparatory to ether.

Illustrative Case, No. 35.—M., about 30. Dark complexion. Strongly built. Good teeth. Said to be "neurotic" and very sensitive.

[1] See *The Administration of Nitrous Oxide and Oxygen for Dental Operations*, 3rd ed. p. 81.

No visceral disease detected. No history of alcohol or drug-habit. Has a dislocated ulnar nerve. Occasional attacks of mental disturbance from acute pain, the hand becoming blue and cold. He is said to be a courageous and business-like man. The family history is "neurotic." Has had anæsthetics before, and has broken two dental chairs and one window. Four men were necessary to hold him down. I anæsthetised him twice. On first occasion, for suturing ulnar nerve; on second, for passive movement of elbow. At first operation he became very violent after a few breaths of nitrous oxide—at a point when most patients are able to control movements on being requested. On second occasion, $\frac{1}{4}$ gr. of morphine was given before nitrous oxide-ether sequence. Mouth-prop inserted. After a few inhalations he began violent kicking. Surgeon and four nurses required to restrain movements. Large quantities of ether needed to obtain relaxation. In 8–10 minutes relaxed. Administration about 25 minutes. Whilst coming round, side to side movements of head began, with rigidity, shouting, and kicking. Restraint again needed. Very violent. He bit himself whilst trying to bite me. $\frac{1}{4}$ gr. more morphine given. A few weeks later he was anæsthetised by some one else. A dose of bromide of potassium and chloral given beforehand. A rather better result obtained, but still great difficulty.

So far as the author is aware there is no adequate explanation of such cases as the above. Sometimes one may find peculiarities of this kind displayed by patients closely related to one another. This was the case in the patients to whom the author administered nitrous oxide and oxygen (*vide supra*). On other occasions the recalcitrant patient has had a family history of insanity.

The author has fortunately only once failed to induce anæsthesia in general surgery. The patient, a thick-set man of 46, was a great smoker, moderate drinker, and gave a history of having damaged furniture to the extent of £40 when a dentist endeavoured to anæsthetise him with nitrous oxide. A gradual administration of the A.C.E. mixture was tried, but without success. The "gas and ether" sequence was next attempted, but this rapidly induced so much maniacal excitement that no operation could be performed. There was a history of insanity in the family.

Jaw Spasm or Trismus: Spasm of Thoracic and Abdominal Muscles leading to embarrassment of Breathing.—These conditions, which may culminate in respiratory arrest, will be considered in the following chapter.

Obstructive Stertor.—The various forms of stertor have already been discussed. As the conditions capable of causing this sound may, under certain circumstances, culminate in

respiratory arrest, the management and treatment of stertor will also be considered in the following chapter.

Stridor.—For similar reasons the treatment of laryngeal stridor will also be dealt with in the following chapter.

Early Shallow Breathing: False Chloroform Anæsthesia.—When this condition, which has already been fully described (pp. 72, 394, 400), becomes established, it must either be treated (1) by administering a few breaths of ether vapour; (2) by peripheral stimulation, *e.g.* lip friction, face friction, pinching, or otherwise stimulating the patient in the hypochondriac region; (3) by very slightly obstructing the air-way, *i.e.* by gently pushing the lower jaw backwards, so that snoring is artificially induced, and the breathing is made to become deeper and quicker; or (4) by opening the mouth and exciting vomiting by stimulating the fauces. The temporary substitution of ether for chloroform generally produces a satisfactory effect in a short time.

Late Coughing, Retching, and Vomiting.—Speaking generally, coughing should be kept in abeyance, for it is likely to inconvenience the operator in most operations, and more especially in abdominal, ophthalmic, and bladder cases. If it be difficult to abolish cough when using ether, chloroform should be substituted; but care must be exercised in effecting the change owing to the free intake of chloroform vapour during the deep inspirations between the coughs. As already explained, there are some cases in which an occasional cough is a positive advantage, in that it keeps the air-passages free. In persons with much bronchitis, or with any affection accompanied by pulmonary or bronchial secretion, an occasional cough is to be encouraged. Coughing is nearly always preceded by deglutition movements, so that should the administrator desire to keep his patient free from cough, he should narrowly watch the behaviour of the larynx. The possibility of epistaxis or hæmoptysis taking place during anæsthesia and giving rise to cough must not be forgotten.

Retching and vomiting, like coughing, never occur during very profound anæsthesia. They are met with either before true surgical anæsthesia has become established, or whilst the patient is emerging from the effects of the anæsthetic. It

is the duty of the anæsthetist to do all in his power to prevent their occurrence whilst the patient is under his charge. Retching and vomiting are objectionable as complications of surgical anæsthesia for at least three reasons. In the first place, the movements of the patient's abdominal and thoracic parietes may embarrass the operator, or actually render the operation hazardous or impossible; in the next place, should there be food present in the stomach, its discharge may interfere with the administration, or endanger the life of the patient; and lastly, with certain subjects under chloroform, there is a liability to syncope during the act of vomiting. To avoid the *contretemps* in question, the anæsthetist should give the anæsthetic as speedily as is compatible with comfort and safety, and should keep the patient deeply under its influence. An intermittent inhalation will be very liable to lead to swallowing, retching, and possibly actual vomiting.

Some patients are much more liable than others to retching and vomiting during anæsthesia. The most liable appear to be children and adults of both sexes who are the subjects of nasal or naso-pharyngeal catarrh, the stomach showing a tendency to eject the swallowed mucus which it contains even when anæsthesia is comparatively deep. The afferent impulse which starts the vomiting in these cases is sometimes furnished by an intra-abdominal manipulation. Flabby young men and women with muddy complexions, and persons who are, as it is said, of "bilious temperament" or liable to "sick headaches," may also give trouble by unexpectedly vomiting during an operation. Persons of spare build, as well as the aged, are not nearly so liable to vomit as those of opposite types.

When once the patient has been placed fairly under the influence of the anæsthetic, the administrator may usually avert vomiting. He must watch for the early indications of its approach, and at once increase the depth of anæsthesia. Amongst these indications swallowing is perhaps the best. Sometimes a high-pitched inspiratory sound may indicate a tendency to vomit. Or a shallow form of breathing, with some pallor but with good conjunctival reflex, may be equally suggestive. Or, lastly, an increase in the size of the pupil

may help as a guide, though, if the administrator has been on the alert, he will probably have received earlier warning from other signs. Vomiting is much less likely to occur when an equable type of anæsthesia is maintained than when the administration is conducted in an irregular manner, the patient at one moment being deeply, at another lightly anæsthetised. It is also easier to avert vomiting under ether or the C.E. mixture than under chloroform, for the simple reason that a more profound narcosis may be maintained with the two former than with the last-named agent.

When the symptoms seem to indicate that vomiting is approaching, it may frequently be averted by suddenly and vigorously wiping away mucus from inside the lips, pulling the chin away from the sternum, and quickly re-applying the inhaler. When it is obvious that the *contretemps* cannot be prevented, the administrator should at once turn the patient's head to one side (if it be not already so placed), and raise the opposite shoulder. The teeth usually become clenched at this stage, and little or no air enters the chest, as the larynx is, of course, closed. The lower jaw should be pushed forwards from behind, and in a few moments the duskiness will pass off without difficulty. The mouth-opener shown in Fig. 15 (p. 256) may be very useful in separating clenched jaws during the act of vomiting. Should the patient be feeble, it is not desirable to allow the breathing to become even temporarily suspended, so that an endeavour should be made to expedite matters as much as possible.

Hiccough.—Hiccough seems to be most liable to occur when the intestines are being manipulated or operated upon. It is, however, very rarely met with. It is chiefly inconvenient during abdominal operations, and in cases requiring regularity and tranquillity of breathing. Unfortunately hiccough is difficult to relieve. It occurs with ether as well as with chloroform, and is little if at all influenced by modifying the depth of anæsthesia. The author has notes of a case of gastro-enterostomy in which hiccough occurred and lasted half an hour. Chloroform was the anæsthetic. Directly a Murphy's button was inserted and the stomach distension relieved, the hiccough disappeared.

Sneezing.—Sneezing occasionally, though rarely, occurs during anæsthesia. The author has met with it chiefly in connection with intra-nasal operations. Should it fail to subside when the anæsthetic is pushed, it is best to spray the nasal passages with a dilute solution of cocaine. Sneezing may be so violent as to constitute a distinct difficulty, especially in delicate operations about the face.[1]

Inconvenient Muscular Rigidity.—As has been pointed out, muscular flaccidity can never be relied upon either with nitrous oxide or with ethyl chloride. Excessive smokers sometimes become so rigid under nitrous oxide that it is difficult to obtain satisfactory anæsthesia.

Illustrative Case, No. 36.—M., about 48. Thick-set and powerful, smokes 6 ounces of dark Virginian tobacco weekly. Says that the particular tobacco "affects the head" of those not used to it. Nitrous oxide and oxygen for the removal of four teeth. When partly anæsthetised "hesitating breathing" appeared. Whole body became rigid and tended to turn to the (patient's) left side. Cyanosis from suspension of breathing. Operation difficult owing to posture. Only possible to remove one tooth. Allowed patient to regain consciousness. After two or three minutes again administered nitrous oxide and oxygen, giving more oxygen than before. Much better result, but patient again rigid. Three teeth removed.

Sometimes it is difficult to secure thorough and complete muscular relaxation whatever anæsthetic be chosen, certain parts of the body remaining inconveniently rigid. Athletic patients, alcoholics of both sexes, excessive smokers, and tall, dark, muscular men of nervous temperament, are particularly liable to give trouble in this direction. Patients with a retracted abdomen, such as is common in certain affections of the stomach, may also prove to be difficult subjects so far as the attainment of abdominal relaxation is concerned.

The most persistent and board-like rigidity the author ever witnessed, was in the case of a lady who was very wasted from malignant disease. Oöphorectomy was being performed for recurrent carcinoma of the breast. There was hardly any thoracic respiration, from secondary lung affection. Although chloroform was given to the fullest degree compatible with safety, the abdominal rigidity persisted and rendered the operation exceedingly difficult.

[1] See *Lancet*, 2nd and 16th Dec. 1893.

Reference has already been made[1] to the interesting case of an excessive smoker who remained so rigid under chloroform that it was practically impossible to perform an abdominal operation.

With ether there may be considerable rigidity during the first five or ten minutes of anæsthetisation, particularly in patients such as those just referred to. The difficulty is often referable to such causes as the use of a narrow-bore inhaler, the presence of a restricted air-way, an insufficient allowance of air, or the premature commencement of an operation. In some patients, for example, rigidity will disappear when a Clover's narrow-bore inhaler is replaced by a wide-bore model, or by an Ormsby's inhaler. In others, the substitution of oral or nasal breathing will bring about the desired result. In others again, an increase in the strength of ether vapour and in the air-supply will prove successful. But the most interesting and efficient line of treatment is the temporary replacement of ether by a small quantity of chloroform. As already pointed out, it is necessary to be careful in substituting chloroform for ether; but if this temporary replacement be cautiously effected, it is quite permissible. For example, it will be found very useful, almost as a routine measure, when employing the nitrous oxide-ether sequence for very muscular men, the ether being withdrawn for a minute or so in favour of chloroform just before the corneal reflex vanishes, *i.e.* whilst stertor and masseteric spasm are present. Such a sequence is in reality a nitrous oxide-ether-chloroform-ether sequence, and is specially useful for quickly obtaining muscular relaxation in strong men. Should inconvenient rigidity be present in the later stages of etherisation, when the lid reflex has vanished, about ten drops of chloroform may be cautiously sprinkled upon a Skinner's mask and the ether inhaler re-applied, when the rigidity will usually subside. Should it still persist, chloroform must not be again applied without first permitting the patient to clear his air-passages by a cough.

It is generally supposed that complete muscular relaxation can always be safely secured by chloroform, but this is by no means the case. It is true, that when no operative stimulus

[1] See p. 160.

is at work, the muscular system is generally flaccid, even though the anæsthesia be not very profound. When, however, certain operations are being performed, reflex rigidity is frequently very marked under chloroform; and it may be dangerous to progressively administer this anæsthetic with the object of overcoming it. We have already seen that numerous deaths have occurred during the administration of chloroform for the reduction of dislocations. When, as not unfrequently happens, there is difficulty in obtaining complete flaccidity under chloroform, it is far better to substitute ether than to persist with the first-named anæsthetic. The substitution of ether for chloroform produces, as we have seen, a remarkably powerful effect; and in many cases this substitution is of very great value.

In one case, that of a publican æt. 56, of heavy build, and with a large abdomen, this treatment answered admirably. The nitrous oxide-ether-chloroform sequence had been employed, but it was impossible to obtain complete abdominal relaxation. The operation was for appendicitis. The author, therefore, again returned to ether, giving it freely from an Ormsby's inhaler, and the abdomen quickly relaxed. With the object of ascertaining whether the effect had been purely accidental, a change was again made to chloroform; but the rigidity at once returned, so that it became necessary to finish the case with ether.

As already mentioned when discussing the use of morphine, there are certain cases in which this drug may prove to be of great service in the attainment of muscular relaxation. When all the means above mentioned have been tried and have failed, a subcutaneous injection of this drug may be given as in Illustrative Case No. 30, p. 504.

Reflex and other Movements.—In certain subjects and in certain operations, it may be impossible to abolish all reflex movements without running the risk of administering an overdose. Neurotic and alcoholic patients are most liable to display exaggerated reflexes. Cutaneous incisions about the feet and legs, rectal, urethral, and vesical operations, manipulations within the peritoneal cavity, particularly about the liver, and the dilatation of any of the natural orifices of the body, are liable to elicit reflex phenomena, even during deep anæsthesia. Owing to the comparatively wide margin of safety with ether,

this anæsthetic is specially indicated when it is desired to secure absolute immobility. It sometimes happens that the resources of the anæsthetist are sorely taxed in attempting to abolish a particular reflex. The following case, which has many points of interest, will make this clear:—

Illustrative Case, No. 37.—M., about 38. Fat. Very large thick neck. Full chin; much fat round angles of jaws. A heavily built man. A perfect set of teeth. Suffers from pharyngitis. Slight cough. Nasal passages not very free. Drinks a bottle of brandy a day. Fairly good heart-sounds. Not nervous. Administration begun 10.10 A.M. No food since previous night. Varicose veins, both legs. Administration lasted 2 hours 20 minutes. A.C.E.-ether sequence (see p. 487). No excitement to speak of. Soon stertorous with ether, but muscles rigid, and breathing rather embarrassed, so changed to chloroform (Skinner's mask). Found it necessary to keep Mason's gag in mouth, and tongue-forceps applied. Very narrow workable area. On the one hand (*a*) inconvenient reflex movement; slight phonation; breathing fairly free or only slightly obstructed by spasmodic retraction of tongue; slight or no corneal reflex; pupils variable. On the other, with more chloroform (*b*) slight reflex movement; greatly obstructed breathing—the tongue requiring forcible traction to overcome spasm; no phonation; no corneal reflex; slight duskiness; larger pupils. Difficulties augmented by presence of laryngeal mucus. Quick recovery from anæsthetic followed by heavy sleep.

In this case, which was an exceedingly difficult one, the choice lay between permitting reflex movements of the legs and bringing about a dangerous degree of obstructed breathing.

Clonic muscular phenomena and the curious movements referred to on p. 398 must be regarded with suspicion when they arise under chloroform. They are liable to mislead the anæsthetist, who may mistake them for reflex movements and increase the anæsthetic; they call, however, for opposite treatment.

Fine rhythmic tremor may be met with under all anæsthetics, but it is most common under ether. It chiefly affects the lower extremities, but it may be general. Muscular, nervous men, whose legs are exposed during the course of an operation, seem particularly liable to tremor. As a rule it may be stopped either by altering the position of the legs and feet, or by increasing the depth of anæsthesia. It is rare under chloroform.

CHAPTER XVIII

RESPIRATORY ARREST[1]

In order that the reader may possess a clear idea of the various ways in which respiration may become arrested it is necessary that he should study what has already been said in Chap. III. (**C**. II. **a**) concerning the respiratory phenomena of general surgical anæsthesia and the numerous factors which may influence the character of the respiration. He is also referred to the remarks in Chap. VI. (**C**, **D**, and **E**) as to the subjects most liable to respiratory embarrassment, and the various conditions, local and general, which may predispose to respiratory arrest.

For our present purposes—that is to say, in order that the rational treatment of arrested breathing may be thoroughly understood—respiration may be regarded as a function whose efficient performance is dependent upon the proper working of (*a*) the respiratory pump, and (*b*) the respiratory centre. It is clear that each of these factors is as important as the other. An inexhaustible store of nervous energy will, for example, be absolutely useless should the air-way be occluded or lung expansion prevented; whilst the most patent air-tract and the most vigorous muscles will be equally useless in the absence of motive force.

We may thus say that there are two fundamentally distinct forms of suspended breathing. The first of these (I.) is due to some mechanical interference with the action of the respiratory pump, and, for the sake of brevity, will be termed *obstructive* or *mechanical arrest of breathing*. The second (II.) is due to depression of the respiratory centre, and may conveniently be termed *central* or *paralytic arrest of breathing.*

[1] See footnote (p. 61) on the term "apnœa."

Obstructive or mechanical arrest of breathing may be an incident of such triviality as hardly to merit description, or one of such difficulty and danger as to tax to the utmost the resources of the anæsthetist. Paralytic respiratory arrest is generally a more serious condition.

There are three distinct ways in which obstructive arrest of breathing may take place. It may result (1) from occlusion of the upper air-passages, such occlusion being produced either by (i.) spasm, (ii.) swelling, or (iii.) altered position of parts within or about the upper air-tract; (2) from the presence of some adventitious substance within the upper air-passages; or (3) from some condition which directly prevents lung expansion.

On the other hand, in paralytic cessation of breathing respiration simply comes to a standstill as the result of failure of nervous energy. This failure may be (1) toxic, *i.e.* from an overdose of the anæsthetic acting upon the respiratory centre; (2) anæmic, *i.e.* from cerebral anæmia due to fall of blood-pressure; or (3) reflex (?), *i.e.* from surgical or other stimuli inhibiting the action of the respiratory centre. Toxic arrest of breathing is usually wholly referable to the action of the anæsthetic upon the respiratory centre, but it may be partly due to other agents, such as morphine. Amongst the causes of anæmic arrest of breathing may be mentioned (i.) cardio-vascular paralysis brought about by overdosage; (ii.) surgical shock of the circulatory type; and (iii.) other causes, such as the sitting posture, loss of blood, and the entry of air into veins. Patients with an abnormally slow pulse are liable to this form of arrested breathing during deep chloroform anæsthesia.

Broadly speaking, the embarrassments in breathing which are dependent upon some mechanical interference with the free entry and exit of air take place during light or moderately deep anæsthesia, and are to be corrected by removing the obstruction or impediment which has led to the embarrassment; whilst those respiratory derangements which are dependent upon central, as opposed to peripheral causes arise during deep anæsthesia, and are to be treated by artificially supplying the motive force which has become temporarily paralysed.

There is an interesting and important point which must

be referred to in connection with occlusion of the air-tract. Given that, at the moment when occlusion occurs, the nervous mechanism of breathing is intact, and that there is no condition present which will directly interfere with lung expansion, futile and deceptive respiratory movements will for a time continue, and unless the anæsthetist be on his guard, they will be very liable to mislead him. As a general rule these movements are diaphragmatic rather than thoracic in type. The teaching of the Hyderabad Commission, viz. that the respiratory movements should be watched and taken as an indication of air-entry, is highly erroneous. In order to be certain that respiration is proceeding, the anæsthetist must either *hear* or *feel* each breath, except, of course, when he is employing a bag-inhaler, in which case the movements of the bag may be safely taken as a guide. Should breathing cease from some direct interference with lung expansion, this spurious and deceptive movement of the chest and abdomen will, as a rule, be completely absent, and the same is, of course, true of respiratory failure of central origin.

The accompanying table has been drawn up with the object of showing in a condensed form the various ways in which breathing may come to a standstill during the use of an anæsthetic for a surgical operation.

TABULAR SUMMARY OF CAUSES OF RESPIRATORY ARREST DURING GENERAL SURGICAL ANÆSTHESIA: WITH EXAMPLES

Form of Respiratory Arrest.	Causation.		Examples.
I. Obstrnctive or Mechanical.	1. From occlusion of upper air-passage due to	(i.) Spasm of parts within or about the upper air-tract.	As when masseters and other jaw muscles are spasmodically contracted; when the tongue is spasmodically retracted causing stertor; or when laryngeal spasm takes place causing stridor. See Illust. Cases, Nos. 37, 39, 40, 41, and 43. When some surgical procedure thus causes respiratory arrest the condition may be termed "respiratory shock" (see pp. 74 and 252).
		(ii.) Swelling of parts within or about the upper air-tract; or	As when anæsthesia is being induced, particularly by pure nitrous oxide or by close etherisation, in plethoric, short-necked men with naturally narrow air-way. More common in Trendelenburg than horizontal posture (see Illust. Case, No. 42).
		(iii.) Altered position of parts within or about the upper air-tract.	As when a flaccid tongue falls over larynx owing to altered posture, or when an epiglottic tumour causes sudden obstruction.
	2. From adventitious substances within upper air-passages.		Blood; vomited matter; mucus; pus; portions of morbid growths; extracted teeth, fragments of teeth or stoppings; artificial dentures; mouth-props; portions of instruments; pieces of sponge.
	3. From conditions directly preventing lung expansion.		As trunk weight in prone posture; extreme abdominal distension; and spasm of thoracic and abdominal muscles. When some surgical procedure causes general respiratory spasm the condition may be termed "respiratory shock" (pp. 74 and 252).
II. Central or Paralytic.	1. Chiefly toxic, *i.e.* from overdose of anæsthetic acting upon respiratory centre.		As when ether is administered in an overdose to a healthy subject.
	2. Chiefly anæmic, *i.e.* from cerebral anæmia due to fall of blood-pressure.	(i.) From cardio-vascular paralysis produced by overdosage.	As in chloroform overdosage.
		(ii.) From surgical shock; or	Illust. Cases, Nos. 54, 56, and 67.
		(iii.) From other causes, such as the sitting posture, hæmorrhage, and the entry of air into veins.	Illust. Case, No. 71.
	3. Reflex (?), *i.e.* from surgical or other stimuli inhibiting the action of the respiratory centre.		Illust. Case, No. 48.

I. TREATMENT OF OBSTRUCTIVE OR MECHANICAL RESPIRATORY ARREST

1. OBSTRUCTION DUE TO SPASM, SWELLING, OR ALTERED POSITION OF PARTS WITHIN OR ABOUT THE UPPER AIR-TRACT

The treatment of threatened or complete occlusion of the upper air-passages dependent upon spasm, swelling, or altered position of parts within or about those passages is to remove the cause of the obstruction.

As has been frequently pointed out in preceding pages,

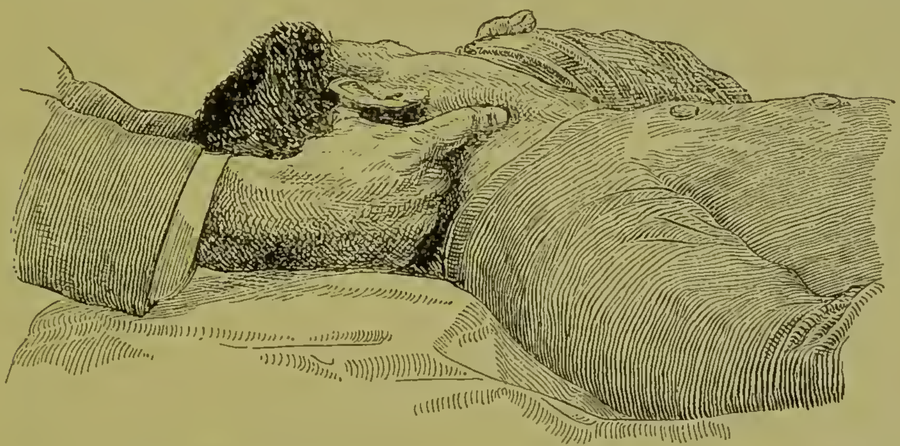


FIG. 68.—The Finger of the Administrator pushing the Lower Jaw forwards.

muscular spasm is a fruitful cause of occlusion, for it may come into play at several points within the upper air-tract. In a large percentage of surgical cases it is necessary to counteract this tendency to spasmodic closure of the air-way by keeping the lower jaw pressed forwards from behind (Fig. 68). This procedure has the effect of bringing the base of the tongue and the epiglottis away from the pharyngeal wall, in which situation they are often held by muscular spasm. By means of the laryngoscope it is not difficult to demonstrate this recession of the epiglottis from the pharynx when the lower jaw is pressed forwards. Should there be much masseteric spasm and stertor, it is sometimes necessary to push the lower jaw forwards from both sides before breathing will freely take place. In some cases, moreover, the front teeth, by over-

lapping the lower, prevent the lower jaw from coming forwards, so that the teeth must be disengaged before breathing can be re-established. Under such circumstances as these the insertion of a small mouth-prop may be advantageous; but it is important to adjust it in such a way that the lower jaw may ride forwards upon the upper. The best plan is to place the prop of Fig. 16 (p. 256) between the *back* teeth so that it acts as a roller (Fig. 69). If it be inserted as in Fig. 70, between the *front* teeth, it may be impossible to move the lower jaw forwards, and respiratory embarrassment may increase rather than diminish. There are certain cases in which breathing will not proceed when the mouth is widely opened, the explanation being, as Dr. Bowles has pointed out,[1] that the base of the tongue is thrown against the pharyngeal wall; and in such it will be necessary either to use a very small prop or to dispense with one altogether. In separating clenched jaws the mouth-opener of Fig. 15 (p. 256) will be useful. If no such appliance be at hand, the forefinger, or the closed blades of a Mason's gag, should be passed into the mouth through the space immediately behind the last molar teeth.

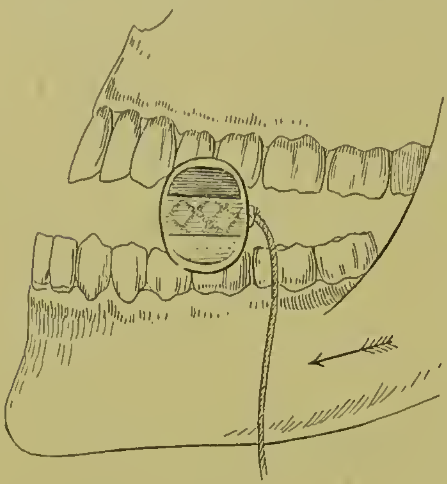


FIG. 69.

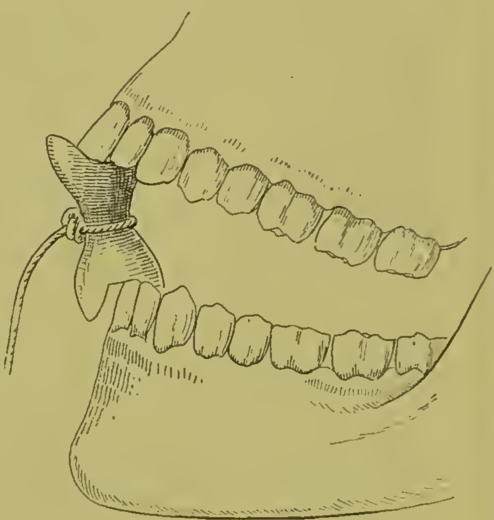


FIG. 70.

Pulling the chin away from the sternum,[2] or completely

[1] *Op. cit.*

[2] This was recommended by Clover, as a useful procedure, as far back as 1874. See *Brit. Med. Journ.*, 14th February 1874, p. 201. He made the following important remarks :—"The act of swallowing is usually performed well enough: but, if the anæsthetic have produced sufficient effect upon the patient to interfere with reflex movements, then the deglutition may be delayed at the moment

extending the head over the end of the operating-table, is often of use in the treatment of obstructed breathing, the beneficial effects being due to recession of the epiglottis from the laryngeal orifice. The author has in more than one case heard a distinct sound such as might be made by the sudden opening of the larynx, at the moment of extension, and respiration has at once recommenced. The extension is most likely to be of use to patients with free nasal passages and thin necks. In thick-necked, muscular subjects with nasal obstruction, extension of the head will of itself be useless as a remedial measure. In conjunction, however, with disengaging the teeth and pushing the lower jaw forwards, as above described, the extension is often distinctly valuable.

In the event of the foregoing treatment proving unsuccessful, the mouth must be opened, a Mason's gag inserted, and the finger passed to the back of the throat to separate the tongue and epiglottis from the pharynx. Temporary arrest of breathing is frequently due, as Clover pointed out, to partially performed deglutition; and the presence of the finger-tip within the pharynx will often lead to a completion of the act of swallowing and so to renewed respiratory action. Should breathing still remain suspended, the tongue-forceps must be applied, and vigorous traction made; and in the vast majority of cases this measure will quickly have the desired effect. Should it not succeed, the chest must be forcibly compressed with the object of overcoming the occlusion by increased intra-thoracic pressure; and should this not answer, formal artificial respiration must be tried.

In addition to laryngeal closure from partially performed deglutition, we have seen (p. 60) that the larynx may become obstructed in two other ways, viz. from collapse of the arytæno-epiglottidean folds, or from spasm of its sphincter muscles. In all forms of laryngeal occlusion the treatment is practically the same. Minor degrees should be treated by suspending the anæsthetic, briskly rubbing the lips, and pushing the lower jaw forwards. When the spasm is

when the epiglottis covers the larynx. Raising the chin, and pulling it as far as possible away from the sternum, is usually sufficient to obviate this source of obstruction.

dependent upon the local irritation of mucus, it is usually best to allow the patient to regain his swallowing and coughing reflexes, and the spasm will quickly subside. As a general rule, laryngeal spasm is met with during moderately deep anaesthesia. Generally it is best to lessen rather than to increase the depth of narcosis. In obstinate cases, when the stridor becomes more and more intense, and increasing cyanosis testifies to the deficient air-entry, it may be necessary to open the mouth and vigorously apply the tongue-forceps. Lord Lister has urged the importance of this prompt treatment when laryngeal occlusion takes place under chloroform; and he believes that tongue-traction acts reflexly in opening the larynx. Should it not succeed, artificial respiration may be tried, but it is not likely to be successful. It is certain that tongue-traction does not directly bring the epiglottis away from the larynx, as was at one time believed. The author has never known true laryngeal spasm to completely arrest respiration under ether. In fact, he has notes of several cases in which a change from chloroform to ether has caused the spasm to at once subside. The condition is most common under chloroform.

The measures above described will generally succeed in opening an occluded air-tract, but in certain cases (which are fortunately highly exceptional) they will fail; and under such circumstances laryngotomy must be performed. To those who have had but little experience it might seem that this treatment could only be justifiable for the relief of obstruction dependent upon the presence either of adventitious substances or of morbid states; but such a view is erroneous. When certain factors combine, it may be impossible to overcome the occlusion by any other mechanical means. When, for example, the neck and throat muscles of a powerful and obese subject are thrown into a state of intense spasm, and when the tongue, fauces, laryngeal folds, and other adjacent structures become so engorged and swollen that the air-way is completely closed, nothing short of laryngotomy may be of any avail. (See Illust. Cases, Nos. 42 and 44.) In such subjects deep stertor is, as we have seen, very common; it readily passes into occlusion; general asphyxial spasm results; and

the last straw is furnished by swelling from general venous engorgement.

In the event of laryngotomy failing to re-establish breathing, artificial respiration by Silvester's method (*vide infra*) must be immediately commenced, and in the vast majority of cases in which remedial measures have been carried to this point recovery will take place. But in certain cases the asphyxial condition present—a condition originally brought about by an occluded air-tract—gradually or rapidly becomes characterised by so much *general* respiratory spasm that even though an opening has been made into the occluded passages it may be impossible to set the respiratory pump going by the usual means. As we shall see when discussing respiratory spasm as one of the conditions capable of directly preventing lung expansion (*vide infra*, p. 551), the remedy to be adopted in such cases is lung inflation through the laryngotomy tube.

It is in cases of this class that venesection is likely to be of use, but it should only be resorted to as a secondary measure, the main chance lying in quickly obtaining an entry of air to the lungs. The immediate cause of death in these cases would appear to be cardiac failure due to over-distension of the right cavities,[1] and venesection is hence indicated.

It is probable that lowering the feet, by bringing the patient's body *across* the bed or table, is advantageous; but here again such treatment must not be allowed to interfere with artificial respiration.

Respiratory arrest from alteration in the position of parts within the upper air-passages may sometimes be seen during deep anæsthesia, as when a patient is turned from the lateral into the supine posture, the flaccid tongue at once falling over the glottis. Similarly, pedunculated growths of the epiglottis or naso-pharynx may, in certain postures of the body, bring breathing to a standstill. In each case the treatment is simple and self-evident.

[1] Venesection was practised by Dr. John Reid in the treatment of asphyxia (see Johnson's *Essay on Asphyxia*). See also an interesting case of drowning reported by Mr. J. F. Briscoe (*Brit. Med. Journ.*, 23rd September 1899), in which venesection apparently saved the patient. The venous engorgement was so intense that retinal hæmorrhage and temporary blindness occurred.

The following cases may be of interest as illustrative of some of the points to which reference has just been made.

Illustrative Case, No. 38.—M., 52. Thin. Nearly edentulous. Grey hair. Apparently a good subject. Radical cure of hernia: three quarters of an hour, "gas and ether." Very hot day. No struggling or difficulty. Operation commenced before corneæ quite insensitive. The respiration before this had been quite good, regular, and unembarrassed. Almost immediately after incision, condition as follows:—Cornea sensitive; some movement of arms; high-pitched crowing breathing; pursing of lips; cyanosis. Mouth opened with fingers, and tongue hooked forwards. Slight, if any benefit. Suddenly, without obvious cause, respiration became regular and deeper, and it then became possible to continue the anæsthetic. No further difficulty.

Illustrative Case, No. 39.—F., 33. Thin. Pink complexion. Tall. Brown hair. Good teeth. Very nervous. Examination of cervix uteri. "Gas and ether." Administration lasted 30 minutes. No difficulty. Deeply under for nearly whole of examination. Stertor; large pupils; good colour. Allowed to "come round" a little as examination nearly over. Sudden cessation of breathing without noise. Teeth clenched. Abdominal movements going on but no air-entry. Colour soon grew dusky. Could not push lower jaw forwards owing to teeth being interlocked. Wooden wedge inserted. Jaws less rigid. Finger to base of tongue. Breathing immediately recommenced.

The two foregoing cases illustrate the way in which breathing may become reflexly obstructed during light ether anæsthesia. Had the operation in the first case not been commenced till the patient had been placed fully under ether, no such respiratory difficulties would have arisen. Similarly had deep anæsthesia been maintained in the second case till all manipulations had ceased, the breathing would not have undergone the change described. When such states of intercurrent asphyxia are not properly treated they may quickly assume grave proportions and culminate in the condition to which the term respiratory shock has been applied (pp. 44, 74, and 252).

Illustrative Case, No. 40.—M., about 50. Thick-set. Large features. Receding chin. Glazed and red face. Very nervous. Nitrous oxide and oxygen for dental extraction. Mouth-prop inserted. Rather more oxygen than usual given—otherwise method is described on p. 311. Although breathing was at first freely oral, it soon became inadequately nasal. In 30 seconds from commencement, *i.e.* when consciousness barely lost, the patient held his breath. Brisk lid reflex present. Pressure of jaw forwards and pulling up chin did not succeed in starting breathing.

Kept face-piece applied for 15 seconds, when cyanosis from suspended breathing becoming marked, face-piece removed and finger passed between tongue and palate, which were in close apposition. Immediate reflex retching excited. As anæsthesia judged to be insufficient (only about one-half or one-third the usual quantity of nitrous oxide having been inhaled), face-piece again applied. Breathing still refused to proceed. After about 10 seconds, face-piece again removed, and tongue again separated from palate and pharynx. One act of retching. Anæsthesia now judged to be sufficient for short operation owing to intercurrent asphyxial factor. Patient believes he was conscious of second extraction. Some uneasiness and rapidity of pulse afterwards.

In this case the reader should note (1) the type of subject; (2) the early arrest of breathing; (3) the presence of a mouth-prop—sometimes favouring respiratory arrest; (4) the very simple nature of the arrest; (5) the correspondingly simple treatment; and (6) the dependence of the anæsthesia upon intercurrent asphyxia.

Illustrative Case, No. 41.—M., æt. about 40. Bloated, flabby, and very alcoholic. Short stature, short neck, large abdomen. Extremely nervous and tremulous. The lower jaw embedded, as it were, in thick flabby tissues, the patient having a "double chin." Good teeth. Operation, removal of small tumour in mammary region. A.C.E.-ether sequence (p. 487). A.C.E. given gradually on Rendle's mask. Respiration good. No struggling. Some rigidity coming on, Ormsby's inhaler charged with "pure methylated ether" was applied gradually. Respiration at first fairly free, but in a short time some spasm about the jaws came on, and rather suddenly drew the head somewhat forwards so that the chin approached the sternum. This at once stopped breathing. Could not press jaw forwards from behind owing to thick neck: and forcible extension of the head and neck equally impossible because of extreme muscular rigidity. Mouth opened: Mason's gag introduced, and tongue-traction made. Respiration at once became re-established, and normal colour of face returned. No further difficulty beyond that great care had to be exercised to keep an air-way open.

The above case illustrates the difficulties which may arise in anæsthetising a patient of the type described, and the manner in which such difficulties should be treated. No matter what anæsthetic be chosen, fat and flabby subjects, presenting the appearance portrayed, will always be liable to give trouble during the stage of muscular spasm. The sudden arrest of breathing (before the patient was really properly anæsthetised) was doubtless due to spasm of some of the neck and jaw muscles, such as the sterno-

mastoid, mylo-hyoid, etc., the contraction of which suddenly brought the head forwards and the chin downwards, thus throwing the base of the tongue against the pharyngeal wall. In patients of a different type from that described, the obstructed breathing may at once be corrected by the procedure figured on p. 529, by pulling the chin away from the sternum, or by extending the head and neck. But in certain individuals neither of these procedures may be successful, and tongue-traction will hence become necessary. Subsequent experience has led the author to believe that in patients of the type here referred to ether is best avoided.

Illustrative Case, No. 42.—M., about 63. Tall, powerful build. Rather stout, with tendency to double chin. Rather receding lower jaw. Good heart-sounds, except for slight bruit probably due to excited action. Complexion naturally florid, but rather pale from nervousness. Temperate as regards alcohol, but smokes a good deal. Operation, excision of rectum. "Gas and ether" administered some weeks previously for a rectal examination: patient reported to have almost died: four teeth were knocked out during attempts at resuscitation: much cyanosis: tracheotomy nearly performed, but artificial respiration succeeded. Dorsal posture. A.C.E. first on Skinner's mask for 3 minutes: no difficulty. Then on Rendle's inhaler. Soon began to snore. Just as slight rigidity commencing, *i.e.* in 4 or 5 minutes from beginning, changed to ether (Ormsby's inhaler). Slight cough and movement of arms. Gradually breathing stertorous, but corneal reflex still present. Patient placed in lateral posture. Operation (rectal) begun. *Slight reflex movement.* Stertor more pronounced. Some difficulty in pushing jaw forwards. Much spasm about jaws and neck. Operator asked to suspend operation. Mouth opened with difficulty, and tongue separated from palate. Operation resumed. Changed to chloroform (Skinner), but almost immediately had to ask operator to stop operation again. Wooden wedge inserted, and finger passed to back of fauces, and for a few moments some air entered larynx, but breathing quickly ceased completely with intense cyanosis. Corneal reflex present. Mason's gag inserted. Tongue-forceps applied, but air would not enter. *Tongue, soft palate, fauces, and adjacent parts enormously swollen*, so that it was practically impossible to pass finger to epiglottis. Patient put back into dorsal posture. Head extended over end of table. Artificial respiration by Silvester's method attempted, but no effect produced. Tracheotomy rapidly performed by operator. *Artificial respiration still unsuccessful.* Air now blown through the tracheal tube,[1] and with immediate success. Artificial respiration was now possible. Recovery quickly ensued. The

[1] The credit for this prompt action belongs to Mr. Henry Randall Wadd of Richmond, who was present and assisted at the operation.

operation, which was successfully completed under chloroform administered through the tracheotomy tube, lasted 70 minutes. The tube was removed during the recovery period.

This remarkable case is one to which the term respiratory shock may be appropriately applied (pp. 44, 74, and 252). It is probably to be explained as follows. *Predisposing causes of arrested breathing:* excessive use of tobacco; naturally narrow air-way; receding lower jaw; flabby tissues; obstructive stertor, possibly favoured by close method of anæsthetisation. *Exciting causes of arrested breathing:* rectal manipulation during moderate anæsthesia, causing additional (reflex) stertor, and possibly some general (reflex) muscular spasm; rapidly resulting venous engorgement and swelling of tongue, palate, fauces, and adjacent parts. The author has never seen a more remarkable phenomenon than this rapidly supervening and intense swelling. According to this view of the case the first point of interest is the increase which took place in the already existing stertor. Reflex stertor has already been considered (p. 60). The next interesting point is that, in consequence of the intense asphyxial spasm by which the chest was fixed, it was impossible, by the ordinary method of artificial respiration, to obtain an entry of air through the tracheotomy tube. The third, and perhaps the most important point of all is that lung inflation at once re-established breathing.

Illustrative Case, No. 43.—F., æt. about 35. Healthy in appearance. Good chest expansion. Quick but good heart's action. Operation for ruptured perineum. Duncan and Flockhart's chloroform: drop-bottle: Skinner's mask. In 7 to 9 minutes from commencement of administration pupils moderately contracted (about 2½ mm.), breathing quiet and non-stertorous, pulse and colour good. Operation commenced. On several occasions high-pitched crowing inspiration was noted, even though corneæ insensitive and patient apparently well under. The difficulty was overcome by giving more chloroform and pushing the lower jaw well forwards. On one occasion, however, this plan failed, and an asphyxial condition supervened. The mouth had to be opened and tongue-forceps applied. This restored breathing, but the colour remained pale and dusky afterwards. Ether now given on an open inhaler. Pulse and colour gradually improved, and satisfactory anæsthesia was maintained without any difficulty for half an hour. The operator found, however, that the parts were far more vascular under ether than under chloroform, so the latter anæsthetic was again tried. Precisely the same respiratory difficulty as before appeared. The operation, however, was

by this time just finished. The crowing breathing subsided altogether directly the manipulations about the perineum were discontinued.

The above case is of considerable importance as illustrating the occurrence of what may be termed reflex laryngeal obstruction during the use of chloroform. The state was one to which the term respiratory shock may be applied (pp. 44, 74, and 252). Florid, young, and middle-aged patients seem particularly liable to this condition under chloroform during such operations as that mentioned, and the only treatment which is of any avail in obstinate cases is forcible tongue-traction.

Illustrative Case, No. 44.[1]—M., æt. 35. Middle height, well nourished, rather florid. Present general condition good, but has had many rheumatic attacks, which have left him with articular disease and stiffness in many parts of the body. Neck rigid. Can only open mouth about one-quarter of normal extent owing to chronic rheumatoid disease of articulations of jaw. Pure nitrous oxide administered for tooth-extraction. Usual method adopted. Small mouth-prop inserted before face-piece applied. The usual phenomena of nitrous oxide narcosis presented themselves. Tooth extracted. The nitrous oxide had been pushed till respiration underwent the characteristic change in rhythm ; but the admission of air which followed the removal of the face-piece failed to restore the rhythm of breathing. Instead of respiration becoming re-established and the normal colour returning, breathing became more difficult and quickly ceased, as if from some obstruction. It was impossible to push the lower jaw forwards because of its fixity, or to extend the head and neck owing to the rigid and ankylosed spine. The finger could not be passed to the back of the throat by reason of the small aperture between the teeth. Tongue-traction was at once made, but failed to restore breathing. Compression of the thoracic walls was equally unsuccessful. The patient was placed upon the floor and forcible pressure was brought to bear on the sternum, but the thorax was immovable. The face was cyanosed and bloated, the lips purple, the whole body rigid, the chest motionless and fixed. Breathing had been suspended for about 2 or 2½ minutes, according to my reckoning; but it is difficult to speak positively on this point. It was obvious that the only remedy left was laryngotomy. Having my tracheotomy instruments with me, I rapidly opened the crico-thyroid membrane with a pocket-knife and inserted a tube. Breathing at once recommenced. The patient made an uninterrupted recovery.

There are many points of similarity between this and Illustrative Case No. 42. As has been shown, when nitrous

[1] The author published this case in detail in *Journ. Brit. Dent. Association* for 1888, vol. ix., p. 222.

oxide is administered to its full extent, the larynx is often drawn up, as in deglutition, to meet the epiglottis. Should the temporary obstruction thus brought about not pass off spontaneously, as it usually does, all that is necessary in ordinary cases is to push the lower jaw well forwards from behind, or to pass the finger to the back of the throat. But in this case these manœuvres were impossible, owing to the almost complete fixity of the jaw. It is probable that, as in Illustrative Case No. 42, secondary venous engorgement and swelling contributed to the occlusion.

Illustrative Case, No. 45.—M., æt. about 22. Pale: neck much enlarged both sides by sub-maxillary glands: no nasal respiration, probably from presence of adenoid growths. Operation for removal of cervical glands. Teeth kept apart by preliminary insertion of small piece of cork. Ether administered by Clover's inhaler. Respiration difficult. Unable to keep lower jaw pressed forwards by reason of its being deeply embedded in the glandular swelling. Tongue much engorged. A.C.E. mixture tried: no better result. The difficult respiration obviously depended upon the tongue obstructing the oral air-way. Had to keep base of tongue hooked forwards by finger. Eventually had to keep tongue pulled continuously forwards by means of tongue-forceps, and to administer chloroform from one end of a Skinner's mask. By this means respiration became free and all difficulty vanished. Administration lasted one hour.

The above case illustrates the impossibility, in some instances, of pushing or dragging the lower jaw forwards. The difficulty of breathing was due to this cause, for the base of the tongue was in contact with the pharynx and could not be brought away by the usual means.

2. OBSTRUCTION DUE TO THE PRESENCE OF ADVENTITIOUS SUBSTANCES WITHIN THE UPPER AIR-PASSAGES.

Blood may enter the larynx, trachea, or bronchi, either as the result of some surgical procedure about the air-passages or as a consequence of hæmoptysis or epistaxis.[1] The two last-

[1] The author has met with one case of epistaxis under ether, in a young man of about 24. In Dr. Sheppard's notes he finds another case recorded in which epistaxis occurred under chloroform. In the latter case the patient was a man of 62, and the epistaxis came on after struggling. A moist râle in the trachea

named conditions are very rare, but it is nevertheless necessary to bear in mind the possibility of their occurrence. With regard to the entry of blood into the larynx, trachea, or bronchi, as the immediate result of some surgical operation, it is clear that the invasion may take place either from above or from below, and the symptoms displayed by the anæsthetised patient will naturally vary with his general state, the posture, the depth of anæsthesia, the quantity of blood present, and the natural degree of sensitiveness of the air-tract.

In operations within and about the mouth, nose, and throat, small quantities of blood frequently gain access to the larynx and trachea; but, as a general rule, such quantities do not give rise to any serious symptoms either at the time or subsequently; for when the anæsthetic is withdrawn, swallowing and coughing return and the breathing and colour quickly become normal in type. But if, during such operations, the rules to which reference has already been made (p. 184) be disregarded, and if hæmorrhage be free, obstructive symptoms may come about either gradually or with remarkable suddenness, and the anæsthetist may find himself face to face with an alarming state. Should it be necessary to keep up a fairly deep anæsthesia, and should the posture be such that blood cannot flow freely from the mouth, frequent sponging as already described (p. 186) must be practised, the middle finger being used in preference to any sponge-holder. The sponges employed should be, when moist and expanded, about half the size of the patient's fist, and it is important that they should be coarse and free from loose pieces. New sponges which have been allowed to soak in 1 : 20 carbolic lotion and then washed in water should be used, and it is best to have half a dozen of such sponges at hand. The author was once able, by using a sponge of this kind, to entangle in its coarse meshes, and so remove from the larynx and trachea, a clot which measured over four inches in length. In cases of this class a careful watch must be kept for any moist expiratory râle—the first sign that the larynx and trachea are becoming invaded by

was the first indication of the bleeding. On looking into the mouth a good deal of clotted blood was discovered. Hæmoptysis is very rare. The author has never met with it, though he knows of one case in which it occurred, to a slight extent, under ether.

an undesirable quantity of blood. Should this râle become audible the anæsthetic must be at once suspended and withheld until coughing takes place, whilst repeated sponging should be practised. The application of ice-cold water to the face will sometimes help to re-establish the coughing reflex. In some cases the breathing comes to a standstill so quietly that the true nature of the arrest may not be recognised. In gradually increasing obstruction, however, a râle is audible, and progressive cyanosis usually occurs. Should the larynx be naturally insensitive, the hæmorrhage free, and the anæsthesia deep, blood may suddenly invade the air-passages and breathing cease with little or no alteration in colour. Should the withdrawal of the anæsthetic, assiduous sponging, and attention to posture prove unsuccessful in removing blood from the larynx, the chest and the abdomen must be forcibly compressed. As a general rule, this will succeed in expelling blood, but should it not do so, the patient must be partially or completely inverted and systematic artificial respiration performed, care being taken to keep the teeth apart and the tongue pulled forwards. If these measures fail, laryngotomy must be performed, artificial respiration renewed, and, if necessary, a catheter introduced into the trachea with the object of sucking out the obstructing fluid. Lung inflation through the laryngotomy wound may also be tried should artificial respiration fail to effect an entry of air.[1]

During operations upon lung cavities blood may enter the bronchi, and under certain circumstances obstruct breathing. The following interesting case may be quoted :—

Illustrative Case, No. 46.—M., about 45. Has been very ill for several weeks. Thin. Orthopnœa. Dusky. Prominent eyes. Anxious and nervous expression. Quick respiration. Pulse feeble and quick—about 160. Air enters right lung fairly freely. Left side dull and immobile, with amphoric breathing at base. Operation, resection of rib and draining lung cavity. Lies more easily on right than on left side ; but sitting posture most comfortable. Placed partly on right side and partly sitting. A.C.E. mixture given slowly, and then a little ether added to Rendle's inhaler. Breathing quick and somewhat more laboured.

[1] For illustrative cases see *Brit. Med. Journ.*, 24th Feb. 1883, p. 352 (two fatal cases recorded). Also *Lancet*, 7th Aug. 1881, p. 386. Also *Brit. Med. Journ.*, 16th Sept. 1882, p. 531 ; and *Lancet*, 30th Sept. 1882, p. 540.

Deep anæsthesia impossible. Offensive pus evacuated. Some hæmorrhage. Rib excised. Drain inserted. During operation a coarse râle became audible, and though anæsthesia light, colour became more dusky. Placed patient on *left* side in order to keep better lung free from blood and pus. A coarse râle palpable over right lung. Dusky. Pulse very quick and weak. Strychnine injected. Enema of brandy. Brisk corneal reflex, but asphyxial state persisted. Patient still unconscious, though no anæsthetic had been given for a considerable time. As condition did not improve I inserted gag and tickled epiglottis and fauces with finger. This induced cough, and a sponge in fauces now extracted a clot obviously coughed up from right bronchus. Immediate improvement and quick return of consciousness.

The above case is a very good example of intercurrent asphyxia. Symptoms such as these are often erroneously ascribed to the anæsthetic or to "shock."

Numerous cases are on record in which, during anæsthesia, vomited matters have been drawn into the larynx and trachea, and have thus caused fatal asphyxia.[1] As we have already seen, vomiting is of very common occurrence with most anæsthetics, and should the stomach contain undigested solids or liquids there is always some risk connected with the expulsion of its contents. A proper regulation of the diet is not always possible, and there are, moreover, certain cases, *e.g.* those of intestinal obstruction, in which vomiting is a feature of the malady for which an operation is needed. It such cases every care must be exercised by the administrator. The advisability of washing out the stomach has already been discussed (pp. 206 and 230). When this precaution has not been taken, and it is known that the stomach contains semi-solid or fluid matters, the head should be kept upon its side throughout, and in the case of heavily built or obese subjects the opposite shoulder should be raised by a pillow, and a Mason's gag inserted in order to allow of the fauces being rapidly cleared, should occasion require. Unless these precautions be taken, the administrator may suddenly be confronted by an alarming condition—the

[1] Of the 101 chloroform fatalities reported by Kappeler two were due to this cause. For illustrative cases see *Lancet*, 30th Sept. 1871, and *Brit. Med. Journ.*, same date; *Edin. Med. Journ.*, vol. viii. ; two cases reported by Socin in the *Tageblatt der Naturforscherversammlung*, 1879, No. 7 ; *New York Med. Journ.*, 20th Oct. 1883, p. 448 (two cases referred to) ; *Lancet*, 3rd Oct. 1874, p. 504 ; *Brit. Med. Journ.*, 16th Sept. 1876, p. 381 ; *Brit. Med. Journ.*, 24th Feb. 1883, p. 351 ; *Brit. Med. Journ.*, 3rd Sept. 1881, p. 414. A case is also referred to by Dr. Jacob in the *Brit. Med. Journ.*, 23rd Feb. 1884, p. 351.

mouth and nose being full of vomited matter, the jaws tightly clenched, the neck rigid, the breathing completely arrested, and the patient cyanosed. Under such circumstances as these it may be difficult to re-establish breathing in time to avert asphyxial syncope, especially when chloroform has been used and the patient's heart is dilated or feeble. In less urgent cases the larynx, trachea, and bronchi gradually become invaded by vomited fluid, and a state of increasing asphyxia results.[1]

The treatment to be adopted in all cases in which the vomiting of solid or fluid substances takes place is to clear and re-establish the air-way as speedily as possible. The mouth must be opened—if necessary with the mouth-opener—a Mason's gag inserted, the head and shoulders turned well to one side, and the fauces cleared with the finger or sponge. Should obstruction appear to be due to some undigested solid food which cannot be thoroughly reached and removed by the finger, a pair of curved forceps may be used with advantage. If the breathing become seriously impeded, and if the above measures fail to restore it, an attempt must be made, by compressing the sides and front of the chest, to force air past the obstruction. If, however, artificial respiration fail, laryngotomy must be resorted to.

Children, adolescents, and patients suffering from affections of the nose, throat, and adjacent parts may secrete considerable quantities of mucus and saliva, particularly during ether anæsthesia. In some cases an inadequate nasal air-way seems to be the principal factor in the causation of the excessive secretion, a comparatively small quantity of mucus within the naso-pharynx becoming churned up and aerated to such an extent that a copious frothy fluid results. The difficulties referable to the presence of mucus and saliva are of two kinds. They either (*a*) depend upon the local irritant action of these secretions; or (*b*) they come about from the secretions themselves actually blocking, to a greater or less degree, some

[1] This would appear to be the most probable explanation of a case reported by Mr. Carter Braine (*Trans. Soc. Anæsth.*, vol. vii., p. 12). The patient was a fat woman of 65, a bronchitic subject with intestinal obstruction. She had recently had champagne. There was frequent vomiting. A light chloroform anæsthesia was skilfully maintained, the patient being in the lateral posture. The ears became dusky, the breathing moist, and gradual asphyxia supervened.

portion or portions of the air-tract. (*a*) Coughing, repeated swallowing, laryngeal spasm, retching, and vomiting, all of which phenomena have already been discussed, may be excited by the presence of mucus within or about the upper air-passages. With such anæsthetics as ether and chloroform it is probable that the secretion in question acquires an irritant character by reason of the absorption of the vapour which is being administered. Respiratory difficulties dependent upon this local action of mucus rarely give cause for anxiety; although they may, if persistent, culminate in a more or less pronounced degree of asphyxia, the true nature of which is liable to be overlooked. Thus, the association of constantly recurring deglutition movements, with more or less continuous laryngeal spasm, may in certain unsatisfactory subjects lead to laboured breathing, cyanosis, pulse-feebleness, or even pallor—phenomena which may erroneously be ascribed to "surgical shock" or "chloroform syncope." (*b*) When the breathing is vigorous, as is usually the case during ether anæsthesia, the obstruction caused by mucus is rarely sufficient to lead to respiratory arrest. It may produce some embarrassment in breathing, with duskiness or even cyanosis, but unless the anæsthesia be exceedingly profound no further trouble usually arises from this quarter. At the same time the moist bubbling or rattling respiration which is so often associated with deep ether anæsthesia generally indicates some want of skill on the part of the anæsthetist, and in certain cases may be taken to foreshadow the occurrence of respiratory after-effects (p. 359). The presence of mucus within the upper air-tract is most likely to constitute a danger when certain other conditions predisposing to respiratory arrest are present. Thus, if deep chloroform anæsthesia be induced whilst the larynx and trachea contain viscid mucus, respiratory arrest may readily take place, the mucus acting as the "last straw." We have already seen (p. 493) that this is the reason why great caution is necessary in passing from ether to chloroform anæsthesia, and that the change from the first to the second anæsthetic should never be made when laryngeal mucus is known to be present without first allowing the patient to clear his air-passages by a cough. If this rule be not followed,

the anæsthetisation of the patient to the usual degree may be unexpectedly attended by stoppage of breathing. Some years ago, before the author clearly appreciated this fact, he met with one or two cases in which breathing ceased in this way. The patients in whom such a cessation of breathing is most likely to prove dangerous are the very young and those whose air-passages have become narrowed as the result of some pathological state. If, in anæsthetising an infant, chloroform be substituted for ether, and breathing cease from the presence of viscid laryngeal mucus, there may be difficulty in restoring it. The author once met with such a case. When the breathing ceased he applied chest compression several times, but though he was able to force air *out* of the chest the elastic recoil was apparently not sufficiently powerful to overcome the obstruction caused by the viscid mucus and to draw air *in*. Fortunately breathing spontaneously recommenced; but the case taught one how dangerous it may be to change from ether to chloroform during deep anæsthesia. The respiratory arrest which sometimes takes place during the anæsthetisation of patients whose air-passages have become narrowed by disease, may also have as its immediate cause the presence of mucus within the narrowed tract. For example, a case of enlarged thyroid may be complicated by the presence of tracheal or bronchial catarrh, and if anything more than a light chloroform anæsthesia be secured breathing may cease in the manner indicated. Lastly, respiratory arrest may be brought about by mucus entering the larynx as the result of suddenly changing the patient's posture.

Illustrative Case, No. 47.—F., about 18 years. Healthy looking. Good condition. Removal of small thyroid tumour. C.E. for 3 minutes. Chloroform for remainder of administration. When the patient was ready the neck was completely extended, with a pillow under the shoulders. Deep anæsthesia. No difficulty during operation. One slight attempt to cough out small amount of mucus. Cough soon subsided. When operation was nearly finished, the patient being well and properly under, with no sound of mucus in air-passages, the pillow under the shoulders was gradually moved towards the head, so as to lessen extension of the neck. The breathing immediately ceased and the pupils dilated.[1] The chest

[1] This sudden dilatation of the pupil, the result of sudden and complete obstruction to the passage of air during deep chloroform anæsthesia, is a striking phenomenon. The author has observed it in several cases.

was compressed a few times and at each compression there was an audible sound of air passing through fluid (mucus). No further difficulty ensued.

In the above case mucus had been accumulating in the naso-pharynx, and was thrown into the insensitive larynx by raising the head.

When mucus tends to accumulate, an attempt should be made to ascertain the cause. Some inadequacy in the air-entry is often present; and the substitution of free oral for inadequate nasal breathing may quickly have the desired effect. The head should be kept well upon its side, the dependent cheek frequently wiped out and the fauces cleared by means of coarse sponges. Should these simple measures fail and the mucus be causing an undesirable degree of respiratory embarrassment, the anæsthetic must be withheld and one or two coughs encouraged, after which a change to chloroform may be cautiously effected. If breathing tend to become or actually become arrested, and if it cannot be reflexly restored by throat sponging or other stimuli, chest compression and other measures which have been advocated in dealing with respiratory arrest from the presence of blood must be applied.[1]

There is nothing worthy of special notice regarding the presence of pus within the upper air-passages. It may gain access in various ways; and any difficulties connected with its presence must be treated as described above.

Portions of morbid growths, pieces of necrosed bone, etc., may become dislodged during certain operations within the nose, mouth, naso-pharynx, and larynx, and may possibly obstruct breathing. The author has good reason to believe that during operations within and about the nasal cavities, adenoid growths, portions of turbinated bodies, etc. frequently gain access with blood to the trachea and bronchi. But it is exceedingly rare, if the depth of anæsthesia be properly regulated and such operations be conducted with aseptic precautions, for any dangerous condition to arise either during or after anæsthesia.

[1] In the *Brit. Med. Journ.*, 18th Nov. 1882, p. 994, a case is reported in which a child of 17 months died under chloroform. At the autopsy large quantities of mucus were found at and below the bifurcation of the trachea.

Extracted teeth, fragments of teeth, and amalgam or other stoppings are liable, during dental extractions, to fall or fly from the forceps of the operator. Bicuspid teeth have a special tendency to fly from the forceps whilst being extracted. In most cases no harm results from the escape of such bodies either into the mouth or throat. But there is nevertheless need for the greatest caution during the use of anæsthetics in dental surgery, seeing that several cases are on record in which alarming and even fatal symptoms have arisen from the entrance of foreign bodies of this class into the larynx or trachea. The accident seems to have taken place, in most cases, during a deep inspiration. When anæsthetising patients for these operations the head should be arranged as vertically as the requirements of the operator may permit; for when the head is thus placed, all substances which may escape from the forceps will tend to fall upon the tongue or floor of the mouth, from which situations they may be immediately removed. The head, moreover, should be adjusted so that it is in a line with the body; for if it be extended, the act of swallowing—nature's safeguard against the accidents under consideration—will be difficult or impossible. If a tooth, stump, or fragment should escape into the pharynx, and if it should not be immediately swallowed, it may remain for a considerable time in the epiglottic region, and may ultimately pass into the œsophagus or be forced away by coughing. Shell-like fragments of teeth are more liable than weightier bodies to enter the larynx, owing to their being more easily swept along by the inspiratory current. Should any of the foreign substances under consideration gain access to the larynx or trachea during anæsthesia, certain symptoms may occur at the moment of their entry. Coughing of a spasmodic character may thus be excited; and this may at once dislodge the substance. Sometimes the coughing is so slight as to escape notice. In other cases the foreign body lodges in the larynx and sets up urgent symptoms, such as stridor, cyanosis, and complete cessation of breathing.

In a case reported by Mr. Claremont in 1858 (*Lancet*, 15th May 1858, p. 477), some fragments of teeth entered the larynx during chloroform anæsthesia. When the patient became conscious, after the operation

was over, coughing occurred, and a complaint was made of some soreness about the chest. There were, however, at the time, no distinct symptoms of the presence of the fragments. General bronchitis followed. Subsequently the fragments were coughed up from the lungs and the patient made a good recovery.

A case is also mentioned in the *Dublin Med. and Chem. Journ.* for 1834, in which "the root and fangs of a lower molar" entered the right bronchus after extraction. Death supervened in eleven days.

Another case is quoted in the *Edin. Journ.* for 1834, in which an entire lower molar entered the lung. It was coughed up on the eleventh day, and the patient recovered.

In the *Brit. Journ. Dent. Science*, vol. xxii., Jan. 1879, p. 7, a case is related in which a large amalgam stopping shot from a tooth during extraction under nitrous oxide, and presumably entered the larynx. Fortunately the patient coughed it out immediately after the effects of the anæsthetic had passed off.

See also *New York Med. Record*, 4th November 1882, p. 517. Also *Trans. Odont. Soc.*, vol. iii., new series, p. 36.

In a case referred to in the *Brit. Med. Journ.*, 18th Feb. 1899, p. 401, an extracted tooth entered the larynx during nitrous oxide anæsthesia, causing extreme cyanosis. Subsequently there was a feeling of tightness in the throat, aggravated by speaking or by change of posture. No breath sounds were audible over the left lung. Death took place in twelve days. At the necropsy the tooth was found in the left bronchus.

A case has lately been reported to the author in which a medical man, whilst sponging out the throat during a dental operation under ether, inadvertently pushed an extracted tooth backwards. It was hoped that the patient had swallowed the tooth. For three weeks she suffered from certain chest symptoms, which she ascribed to the anæsthetic. At the end of this time the tooth was coughed up and no further trouble followed.

During the extraction of teeth under anæsthetics the operator should be most careful to leave nothing whatever loose in the mouth. He should remove each tooth or stump as it is extracted, and see that there is nothing hanging to the forceps when that instrument is reintroduced. When several upper roots have to be extracted, the back of the throat may be protected by the corner of a cloth or by an open-meshed sponge, too large to be gripped by the pharynx. Although the avoidance of accidents of this kind should rest with the operator, the administrator may often assist the latter. Thus it is possible for the administrator to place a finger across the back of the mouth between the tongue and palate; or to press the tongue against the palate and so shut off the oral cavity from the pharynx.

Should symptoms pointing to the entrance of a foreign body into the larynx manifest themselves, the patient should be bent forwards in the operating-chair and narrowly watched. The spasmodic cough and other symptoms may now quickly subside, the foreign body having either been coughed into the mouth and swallowed, or having become so placed in the air-passages that for a while it sets up very few symptoms. Should coughing, duskiness, and difficulty of breathing continue, the back may be smartly slapped, whilst the patient is bending forwards. Should this not succeed, the patient may be turned on his side with the object of facilitating the exit of the substance. If this fail, inversion should be adopted. This last-named procedure, although open to the objection that it may cause the foreign body to be coughed into the larynx, where it may induce spasm, has answered in several cases, and may certainly be tried if the symptoms are of sufficient urgency. Should signs of laryngeal spasm (high-pitched stridulous breathing, cyanosis, embarrassed and ultimately suspended breathing) supervene, no time must be lost in opening the larynx at the crico-thyroid space, and, if necessary, performing artificial respiration through the opening thus made.

Other substances, such as artificial dentures, pivoted teeth, portions of or entire mouth-props or corks, portions of instruments [1] used in laryngeal, dental, or similar operations, pieces of sponge, etc., may gain access to the larynx, and set up symptoms of an asphyxial character requiring very prompt measures. An interesting, though unfortunately a fatal case,[2] in which an artificial denture became impacted in the larynx, occurred in 1872, and is well worthy of notice. An unattached cork has been known to slip from between the teeth and asphyxiate a patient under nitrous oxide.[3] The

[1] A very interesting and instructive case, in which the broken blade of a pair of extraction forceps entered the larynx, was reported by the late Sir William MacCormac (see *Lancet*, 2nd Jan. 1886). The patient was lying in the semi-recumbent posture on a couch with the head raised by pillows. Chloroform was given. The broken blade entered the larynx during two or three deep inspirations. A violent fit of spasmodic coughing immediately took place. The patient became livid and much distressed. Subsequently dyspnœa, cough, and pain were complained of, and Sir William MacCormac, by a skilfully planned operation, removed the foreign body, through a tracheal opening, from the right bronchus.

[2] See *Brit. Med. Journ.*, vol. i., 1872, p. 419.

[3] See *Med. and Surg. Reporter*, 1867; and also Agnew's *Prin. and Prac. of Surgery*, vol. iii. p. 44.

spring of a Buck's gag has also been known to enter the larynx and eventually lead to a fatal result. These facts should teach us how necessary it is to see that all dental mouth-gags are firmly secured by string or whip-cord, and also that all spring-gags should be avoided in dental surgery. A case has been recorded in which a sponge, used in the course of a dental operation, caused the death of a patient by becoming impacted in the upper air-passages.[1] A "quid" of tobacco has been known to cause asphyxial symptoms during anæsthesia.[2]

3. OBSTRUCTION DUE TO CONDITIONS DIRECTLY PREVENTING LUNG EXPANSION

We have already studied (p. 57) the respiratory phenomena of anæsthesia, and have seen that, as a general rule, most of the inspiratory work is done by the diaphragm. It is therefore very important that the descent of this muscle should be unimpeded, particularly in those cases in which the thorax would be unable to take on the additional work which would naturally fall to its lot in the event of the diaphragm being unable to act. Similarly, it is important to provide for free thoracic expansion, more particularly in cases in which, for some reason or another, abdominal movements are in abeyance. In more than one of the recorded nitrous oxide fatalities (p. 283) tightly-fitting corsets undoubtedly contributed to the accident. Should the precaution of removing all constricting clothing or bandages have been omitted, and the breathing become embarrassed or cease, no time must be lost in removing all impediments to lung expansion, and in performing artificial respiration should this be necessary.

There are certain postures, *e.g.* the prone and semi-prone, in which the trunk weight may tell directly upon chest expansion (see p. 240). Should breathing become much embarrassed or cease, the patient must at once be placed in the dorsal posture and the ordinary means adopted for restoring breathing.

[1] See *Lancet*, 5th Jan. 1901, p. 73.
[2] Fischer, *Deutsche Zeitsch. f. Chir.*, Bd. xv. 188.

In certain subjects, and particularly in those who are elderly, obese, and emphysematous, the lithotomy posture may involve a dangerous degree of respiratory embarrassment, and it may be necessary to place the patient in some other position. The author has, for example, met with one case in which excision of the rectum had to be performed with the patient in the lateral posture.

There are numerous morbid states which, whilst they may be compatible with blood oxygenation so long as the patient is conscious, will cease to be thus compatible directly anæsthesia has been produced. This may be the case, for example, in patients with excessive abdominal distension from ascites (see pp. 169 and 474), or in those with hydrothorax or other pleural or pulmonary diseases. As a general rule, a comparatively light anæsthesia is here indicated, particularly during the period of greatest respiratory distress; and should occasion require, artificial means must be used for maintaining breathing.

One of the most important conditions capable of directly preventing lung expansion is general respiratory spasm. This spasm, as we have already seen, may either arise (1) during the stage of rigidity and excitement (pp. 345 and 408); (2) as the reflex result of some surgical procedure (respiratory shock) (pp. 44, 74, 252, 537, and 538); or (3) as a sequel to occlusion of the air-tract (p. 533). Minor degrees of respiratory spasm are very common during the induction stage of anæsthesia, but the temporary respiratory embarrassment to which this spasm gives rise usually subsides spontaneously, *i.e.* without treatment. In certain types of subjects, however, complete arrest of breathing may take place, and unless remedial measures be promptly adopted this arrest may persist till the heart fails. It is in this way that strong men die in the early stage of chloroformisation. It is in this way, too, that certain cases are to be explained in which patients have died as the result of some surgical stimulus during light or moderate anæsthesia. The supervention of general respiratory spasm in those cases in which breathing has come to a standstill from some obstruction *within* the air-tract constitutes, as we have seen in Illustrative Case No. 42, p. 536, a most formidable complication; for

even when laryngotomy has been performed for the relief of the obstruction, we may find that we have to reckon with an even greater difficulty, viz. fixity and immobility of the thorax. Lord Lister has described one fatal case of this sort, and it is probable that a large number of others have taken place whose true nature has been overlooked.

Many years ago the author met with a somewhat remarkable case of respiratory spasm. The patient was a man of sixty-nine years of age, whose usual pulse-rate was 30 per minute. He was only slightly emphysematous, and not bronchitic at the time. Under the influence of ether his expiration was rather strained. During properly established anæsthesia, breathing suddenly ceased; and though there was no occlusion of the air-way, it was absolutely impossible to move the chest-walls one way or the other by artificial means. The pupils were at the time moderately contracted. Fortunately, breathing spontaneously reappeared after about half or three-quarters of a minute. Subsequent experience has taught that ether should be avoided in such cases.

Mr. Holmes, Dr. Jacob, and others have recorded somewhat similar cases under ether. In two cases referred to in the *Brit. Med. Journ.*, 15th March 1884, p. 508, and 2nd May 1885, p. 887, respiratory failure occurred in patients suffering from goitre, and although tracheotomy was performed and a free passage to the lungs opened up, the chest-walls were so fixed that they could not be moved. In both cases a fatal termination ensued. As already indicated (p. 203), ether is not the most appropriate anæsthetic in such subjects. It is highly probable that the use of forced artificial respiration (p. 553) offers the best chances of resuscitation when breathing thus ceases.

For reasons already given, respiratory spasm under nitrous oxide or ether is not nearly so dangerous as under chloroform. The combination of this spasm with the continued absorption of incarcerated chloroform vapour will, in fact, rapidly destroy life; and this is the explanation of that form of syncope which has so often been described as having occurred early in chloroformisation. If, at the moment when respiration becomes suspended, there is comparatively little chloroform in the lungs and circulation, the wrist-pulse may remain palpable for some time, the heart holding out against the asphyxial strain with a resistance proportionate to its original vigour. If, however, anæsthesia be deep at the moment breathing ceases, the strongest heart may become so rapidly poisoned that the respiratory spasm may be attended or immediately followed by pulselessness.

When general respiratory spasm arises and does not spontaneously subside, the mouth should be opened by means of a Mason's gag, the tongue-forceps applied, the fauces stimulated by the finger and cleared of any mucus that may be present, and artificial respiration by Silvester's method attempted. In the event of these measures failing to restore breathing, it is probably best to perform laryngotomy at once, partly because there may still be laryngeal obstruction present, and partly because, when once a laryngotomy tube has been inserted, it is comparatively easy to apply the treatment which is next indicated, viz. lung inflation. Immediately laryngotomy has been performed an attempt should be made to inflate the lungs by applying the mouth to the tracheal tube, care being taken to close the lips and anterior nares of the patient. As already explained when dealing with occlusion of the air-tract (p. 533), there are certain exceptional cases in which the chest walls cannot be moved by the usual means, even though laryngotomy has been properly performed; and it is in such cases as these that lung inflation holds out the only chance of success. In Illustrative Case No. 42 (p. 536), direct lung inflation undoubtedly saved the patient's life. Inversion should not be employed, for such a measure would only increase the distension of the right cardiac cavities.

Inflation of the lungs, by means of bellows, was the recognised method of performing artificial respiration before the plans now in use were known to the profession. Amongst those who have invented and used specially constructed bellows for lung inflation may be mentioned John Hunter,[1] Sibson,[2] Plouviez,[3] Marcet,[4] Richardson, and Fell.[5] When the simpler and handier methods of Marshall Hall and Silvester began to find favour, inflation of the lungs fell into disuse; and at the present time it is rarely, if ever, employed. There can be no doubt, however, that under the circumstances above narrated lung inflation is the proper treatment.

Lastly, there are certain operations about the thorax and abdomen which may themselves mechanically interfere with breathing. Thus, during the removal of a renal tumour adherent to the diaphragm, complete suspension of breathing

[1] *Asclepiad*, 1890, p. 201 *et seq.* [2] Silvester, *op. cit.* [3] Kappeler, *op. cit.*
[4] *Proc. Roy. Med. Chir. Soc.* vol. iv., 1861-64, p. 45.
[5] *Brit. Med. Journ.*, 1st March 1890, p. 495; *Brit. Med. Journ.*, 16th August 1890, p. 384.

may take place each time traction is made. The treatment of such cases, however, hardly falls within the scope of this work.

II. TREATMENT OF CENTRAL OR PARALYTIC RESPIRATORY ARREST

1. PARALYTIC RESPIRATORY FAILURE DUE CHIEFLY TO THE TOXIC ACTION OF THE ANÆSTHETIC

This form of arrested breathing is typically seen when an overdose of ether is administered to a healthy patient (p. 350). With the C.E. mixture and *a fortiori* with chloroform, overdosage is generally associated with such a fall of blood-pressure that the respiratory arrest may be quite as much due to cerebral anæmia as to the toxic action of the anæsthetic upon the respiratory centre. In the case of pure nitrous oxide, overdosage almost invariably induces muscular spasm within or about the air-passages, so that the respiratory failure is of a somewhat different type to that now under consideration.

In most cases respiratory failure of this kind comes about more or less gradually. The breathing grows shallower and shallower till it ceases altogether; or the standstill is preceded by irregular jerks and inspiratory "catches." In rare cases the arrest takes place with unexpected suddenness. As we have seen, shallow and almost imperceptible respiration does not of itself necessarily imply that danger is present. Other signs must be consulted. So long as the normal colour of the face and ears is not materially altered, the pulse not markedly affected, and the conjunctiva sensitive to touch, feebleness of breathing means very little. But should feeble respiration coexist with a pallid, dusky, or cyanotic complexion, a small, slow, or irregular pulse, and a totally insensitive cornea, the anæsthetic must be withheld, for these signs collectively indicate that complete cessation of breathing is imminent.

When respiration threatens to come to a standstill, without actually ceasing, and the administrator feels certain that the air-passages are not occluded, the anæsthetic should at once be removed, and the lips lightly but briskly rubbed from side to side with a dry towel. Halting and feeble breathing under

chloroform may usually be re-established by lip-rubbing, the immediate effect of which is very often remarkable. The author has frequently known respiration, colour, and pulse immediately to improve on briskly rubbing the lips. Sometimes breathing can only be kept satisfactorily proceeding by this little manœuvre. Should these measures not succeed, respiration must be assisted by pressing, with each feeble expiratory movement, upon the chest walls. Gentle rhythmic pressure upon the sternum with one hand, or similar pressure upon the sides of the chest with both hands, may be made. In one or other of these ways actual cessation of breathing may often be averted.

Should the respiration cease—and this will be known by the absence of all thoracic and abdominal movements, the increasing duskiness of the face, and cessation of all breath sounds—systematic artificial respiration must be resorted to without a moment's delay.

Silvester's Method of Artificial Respiration.[1]—If the patient be lying lengthwise upon a bed, he should be rapidly placed transversely, and his head allowed to hang over the side. Should he be lying upon an operating-table, similar extension of the head may be effected over the end of the table. If he be in the sitting posture at the time of the respiratory failure, he should be at once placed on the ground with his shoulders slightly raised and his head extended. Although it is here assumed that the air-passages are patent, it is best, as a routine practice, to insert a gag, apply the tongue-forceps, and make traction upon this organ in order to be quite sure that it is not obstructing breathing. As is well known, the respiration may become obstructed so inaudibly that an error in the diagnosis of the kind of respiratory failure may easily be committed. Full extension of the head and neck, as pointed out by Dr. Howard,[2] tends to keep open a free air-way. The administrator should stand behind his patient, and, grasping the arms at the elbows, should press them firmly and steadily

[1] See *The Discovery of the Physiological Method of Inducing Respiration in Cases of Apparent Death from Drowning, Chloroform, Still-Birth, Noxious Gases, etc.*, by Henry R. Silvester, 1863.

[2] See *Lancet*, 27th October 1888, and *Brit. Med. Journ.*, 7th November 1888, "On Raising the Epiglottis."

against the sides of the chest (Fig. 71). In the vast majority of cases this pressure will cause an expiration; but should it not do so at once, forcible pressure below the costal margins, and directly towards the diaphragm, may be brought to bear. After the arms have been steadily pressed against the sides for about a couple of seconds, they should be brought deliberately

FIG. 71.—Artificial Respiration by Silvester's Method (Expiration). From a photograph.

towards the administrator, so that they come into the long axis of the patient's body, on either side of his head. This procedure usually has the effect of enlarging the capacity of the chest by causing the pectoral muscles to raise the upper ribs. In this way (Fig. 72) inspiration is effected. The arms should be kept extended for about a couple of seconds, after which they may be again brought to the side as in Fig. 71. These expiratory and inspiratory movements should be repeated regularly and steadily about fifteen times per minute, careful

watch being kept for any spontaneous respiration. If any signs of the latter appear, the natural movements should be supplemented by the artificial till the breathing has become thoroughly re-established. Care must be taken throughout to maintain a free air-way, and not to exert undue and unnecessary force during expiration. Ribs have been fractured, and

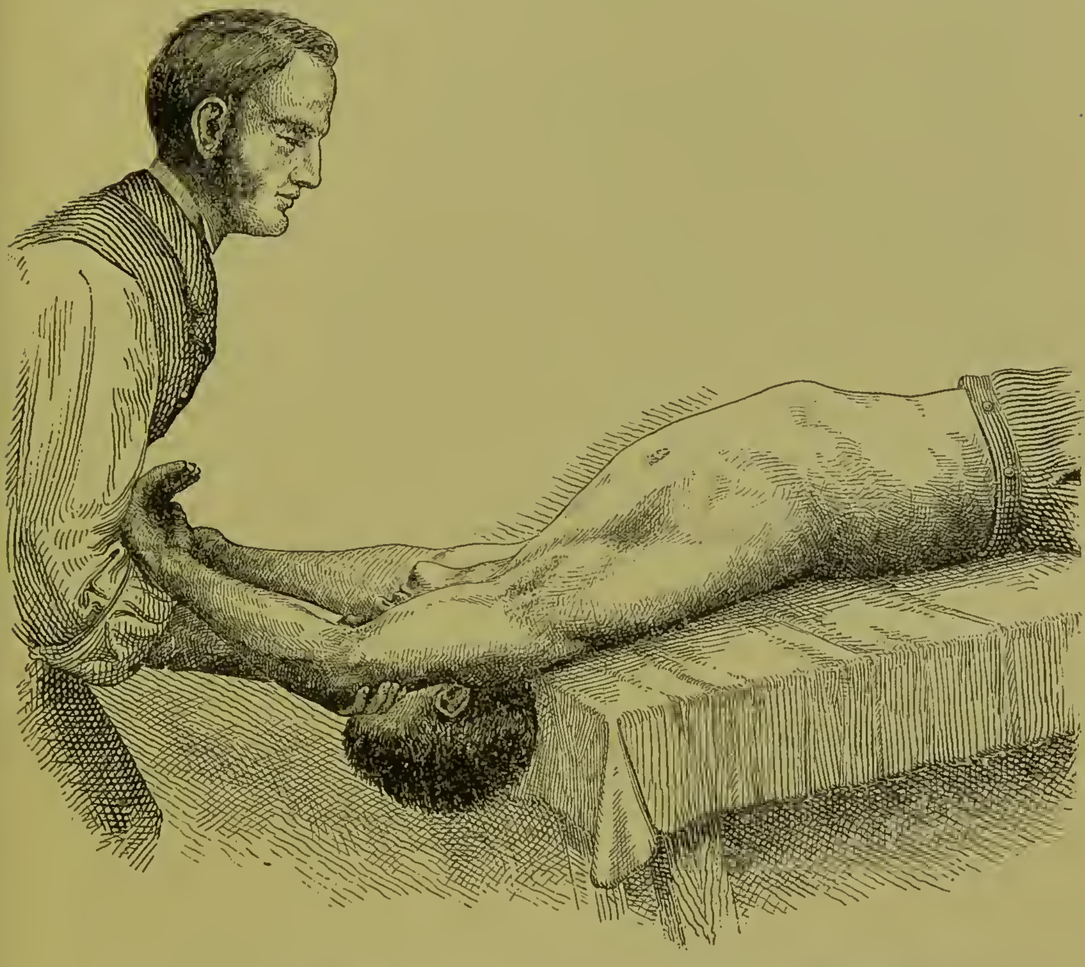


FIG. 72.—Artificial Respiration by Silvester's Method (Inspiration). From a photograph.

rupture of the liver has actually occurred, from too roughly handling the patient.

In *Pacini's* modification [1] of Silvester's method, the operator, having his abdomen against the head of the patient, places his hands in the dorsal fold of the axillæ, and pulls the shoulders towards him with an

[1] Introduced into England by Dr. Bain. See *Lo Sperimentale*, T. xxxvii., 1876, p. 39; *Lancet*, 19th December 1868, p. 799; *Trans. Roy. Med. Chi. Soc.*, 1870, vol. liii. p. 291.

upward movement. The shoulders are then relaxed, and the former movement is repeated.

There are other methods of performing artificial respiration; but, putting aside those in which the chest is inflated by means of bellows, they are all inferior to Silvester's, in that they do not provide for any inspiratory action beyond that resulting from the elastic recoil which follows chest compression.

Chest Compression.—Rhythmic compression of the chest walls, each compression being followed by a removal of the pressure, has already been alluded to as of service in threatened respiratory arrest. As Richardson pointed out,[1] this plan is particularly useful in young subjects, *i.e.* in those with elastic thoracic parietes. Indeed, in the treatment of suspended breathing in children, this simple chest compression usually answers as well as any other method of resuscitation, although, as pointed out above, the presence of mucus within the larynx may prevent the inspiratory recoil which is essential.

Marshall Hall's Method of Artificial Respiration.—In Marshall Hall's or the postural method, the weight of the patient's trunk is utilised to effect thoracic compression, *i.e.* expiration. The patient is placed face downwards, his chest being supported by a pillow or folded article of clothing, and he is then gently rolled on to his side. These procedures are repeated about fifteen times a minute. Whilst the patient is lying in the prone position expiration is assisted by making pressure upon the back.

Howard's Method.—For the performance of artificial respiration by Howard's method,[2] the patient must be so placed that his shoulders are somewhat raised, and his head and neck fully extended. His hands should be loosely tied together and thrown over his head. The administrator, who must kneel astride his patient, spreads open his hands so that his thumbs and little fingers rest upon the inner margins of the free borders of the costal cartilages, the tips of the thumbs being placed over the xiphoid cartilage. Forcible and sudden pressure is brought to bear upwards and inwards towards the diaphragm for two or three seconds. The pressure is then suddenly removed, the administrator resting for three seconds before repeating the procedure. Seven to ten compressions should be made per minute.

The Administration of Oxygen.—This appears at first sight to be strongly indicated. But Lallemand, Richardson, Perrin, and Duroy[3] have found by experiment that common air answers just as well. The first-named observer, indeed, states that common air is actually preferable.

---

[1] "Artificial Respiration: The Theory and the Practice" (*Asclepiad*, 1890, p. 201).

[2] *Brit. Med. Journ.*, 16th August 1890, p. 384.

[3] Kappeler, *op. cit.*

Even if a more extensive trial of oxygen should prove that this gas is preferable to air, the difficulties in the way of keeping it in readiness must always prevent its use save in hospital practice. Dr. Foy[1] and Dr. David Lamb speak strongly in its favour.

Electric Stimulation.—Electric stimulation of the phrenic nerves was originally suggested by Duchenne in 1855 as a means of restoring respiration. He found that by the application of the induced current to these nerves he could produce powerful diaphragmatic contraction in lower animals; and that a similar result could be obtained in the human subject some considerable time after death. He ascertained, moreover, that in animals poisoned by chloroform the electrical excitability of the phrenic nerves remained almost or wholly unaltered.[2] Duchenne advised that each electrode of an induction apparatus should be placed over the lower end of the scalenus anticus muscle, on the outer edge of the sterno-mastoid. The latter muscle should be drawn somewhat inwards. The electrodes having been placed in position, the current was turned on for about a couple of seconds, when the diaphragm was found to contract and an audible inspiration to result. Expiration was assisted by compressing the lower part of the thorax and the abdomen for a couple of seconds. The faradisation of the phrenics was then repeated. By employing somewhat larger electrodes than those at first used, Duchenne found that he was able to call into action other muscles capable of assisting inspiration, such as the sterno-mastoid, trapezius, levator anguli scapulæ, the pectorales, the serratus magnus, and the rhomboidei. Faradisation of the phrenics was used successfully by Ziemssen[3] in 1856, in a case of asphyxia; and the same author has recorded a similarly happy result in a case of chloroform poisoning. In the latter case the current seems to have been applied directly to the diaphragm. Snow[4] relates a case in which a "galvanic apparatus," which happened to be in readiness, proved very suceessful in effecting inspiration in a patient who had ceased to breathe during chloroform narcosis; and in this case also the electrodes were applied to the diaphragmatic region and not to the phrenic nerves.[5] In the fatal cases collected by Snow mention is made of "galvanism" on several occasions. The effects, however, do not appear

[1] *Brit. Med. Journ.*, 23rd January 1892, and *Lancet*, 16th May 1903, p. 1368.

[2] See *De l'Électrisation localisée*, by Duchenne, 1872.

[3] See Kappeler, *op. cit.* p. 131.

[4] *Op. cit.* The current employed was probably an interrupted (faradic) one.

[5] Dr. H. Lewis Jones, who is in eharge of the Electrical Department at St. Bartholomew's Hospital, has kindly compared for the author the effeets produced by faradisation of the phrenies and faradisation in the region of the diaphragm. He finds by experimenting upon himself and upon the anthor that the application of the electrodes over the phrenics, as suggested by Duehenne, produces very distinct diaphragmatie contraction with immediate entry of air to the lungs; whilst the application of the current to the diaphragmatic region produces violent expiratory efforts apparently from the contraction of the intercostal and abdominal musoles. The application of the current to the phrenic nerves in the neck is not always an easy matter; but when once the nerves have been found (and it is easy to tell when this has been accomplished by the effects produced), the inspiratory action of the diaphragm is very striking.

to have been very marked. When readier methods of artificial respiration became known, faradism gradually commenced to fall into disuse. At the present time it is rarely if ever employed, principally for the reason just mentioned, but partly also because of the difficulties in the way of always having at hand an induction apparatus in working order. It is questionable, however, whether faradism should be completely discarded. When an entry and exit of air can be brought about by Silvester's method, any attempt to carry on artificial respiration by electrical stimulation, either of the phrenic nerves or of the diaphragm itself, must be regarded as out of place. Should the chest be rigidly fixed, however, so that all manual methods of artificial respiration prove fruitless, and should an induction apparatus be at hand, faradism of the phrenic nerves should certainly be tried. We have yet to learn whether this immobility of the chest walls—one of the most alarming complications of anæsthesia, and one to which reference has already been frequently made—is the result of spasm of the expiratory muscles. If future observation should lead to this conclusion, faradism may yet be destined to save many lives. An interesting case is reported by Dr. David Lamb (*Lancet*, 16th May 1903, p. 1367), in which the intermittent application of the constant current restored respiration after a prolonged period of cessation.

Should the arrested breathing be associated with a feeble or imperceptible pulse, the artificial respiration may with advantage be combined with partial inversion, as recommended in the treatment of respiratory failure due to fall of blood-pressure (p. 562). Experience leads the author to believe that drugs are of little or no value in the treatment of this form of respiratory arrest.

As already mentioned, patients under the influence of opium, morphine, or other sedatives, are more liable to this variety of arrested breathing than other subjects; and as in Illustrative Case, No. 32, p. 506, delay in the re-establishment of respiration may be quite as much dependent upon the action of the sedative as upon the action of the anæsthetic.

With regard to prognosis we may say that, if a pulse can be detected at the wrist when respiration ceases, and if air can be made to enter and leave the chest, recovery may almost certainly be looked for. Even though the pulse cannot be felt, the administrator should by no means despair, but promptly commence and perseveringly continue artificial respiration. It is almost unnecessary to say that artificial respiration must be kept up so long as there is the slightest chance of restoring the patient. Recovery has been known to

take place some considerable time after all signs of natural respiration and circulation have been in abeyance. The most formidable cases are those in which respiration and circulation almost simultaneously cease, apart from surgical shock as a factor.

As special descriptions have been given of the symptoms which characterise an overdose of each agent, it is unnecessary to append any illustrative cases of this variety of respiratory failure.

2. PARALYTIC RESPIRATORY FAILURE DUE CHIEFLY TO CEREBRAL ANÆMIA

Paralytic respiratory failure during anæsthesia is undoubtedly sometimes due, either wholly or in part, to cerebral anæmia. Leonard Hill has particularly insisted upon this fact in chloroform toxæmia (p. 116), and the author can corroborate his views from a clinical standpoint. In the case of ether the administration of an overdose leads to a paralytic cessation of breathing, which is not as a rule dependent, at all events to any great extent, upon lowered blood-pressure. In chloroform toxæmia, however, the arterial tension is often so reduced that the blood supply to the respiratory centre is more or less suspended, and the breathing fails, quite as much from this cause as from the sedative action of the anæsthetic. Patients with an abnormally slow pulse may display this form of arrested breathing under chloroform, even though the anæsthesia be not pushed to the point at which the corneal reflex vanishes. In one case of this kind the author found it necessary to replace chloroform by ether in order to preserve efficient respiration. Numerous cases of chloroform syncope have been recorded in which the breathing reappeared and disappeared as the trunk was alternately inverted and brought to the horizontal plane, clearly showing the intimate dependence of respiration upon blood-pressure. Other things being equal, patients in the sitting posture are more liable than others to display indications of anæmic arrest of breathing. On the other hand, the respiration of those placed in the Trendelenburg posture is generally conspicuously satisfactory, provided that all obstruction be prevented. In surgical practice anæmic arrest

of respiration not unfrequently comes about from surgical shock. In the opinion of the author, indeed, surgical shock of the circulatory type is a far more common incident of chloroform anæsthesia than is generally believed; and when this shock is acute, respiratory depression or arrest from cerebral anæmia so rapidly follows the circulatory depression that unless the most careful observations be made a wrong interpretation may be put upon the case.

The treatment of anæmic respiratory arrest is artificial respiration, combined with partial or complete inversion. It is, in fact, the same treatment as that described in the following chapter as appropriate in primary circulatory failure of such intensity as to involve respiration. With regard to other remedial measures these must be looked upon as of secondary importance; but should opportunities be favourable, the drugs recommended for the treatment of circulatory failure (p. 590) may be employed whilst artificial respiration is proceeding. Of these strychnine is most likely to be of service, and may be subcutaneously given in doses of about $\frac{1}{40}$th gr.[1]

Several cases illustrating this form of respiratory arrest will be found in the following chapter.

3. PARALYTIC RESPIRATORY FAILURE DUE TO REFLEX INHIBITION OF THE RESPIRATORY CENTRE (?)

The author has notes of one or two interesting cases in which breathing has apparently ceased from what may be termed reflex respiratory inhibition. The following case will illustrate this point:—

Illustrative Case, No. 48.—M., æt. 51. ? A malingerer. Abdominal incision. Ether. Clover's inhaler for induction, then Ormsby's. Well under. Abdomen relaxed. No corneal reflex. Respiration deep and stertorous. Then less full. Good colour. Sudden cessation of breathing

---

[1] Dr. H. C. Wood has kindly sent the author a pamphlet entitled *Strychnine as a Respiratory Stimulant*, which gives his experiments with this drug. In one case of opium poisoning, seven injections, each of $\frac{1}{10}$th gr. of sulphate of strychnine (=about 6 min. of Liq. Strychninæ Hydrochloratis), were given. See also a case of chloroform poisoning (2 oz. swallowed) in which strychnine was apparently of use (*Brit. Med. Journ.*, 20th November 1897, p. 1498).

at moment of incision. Recommenced very feebly and with long pauses. For the first half-minute of feeble breathing colour good, but soon became dusky. Chest compression soon restored respiration.

In another case of which the author has notes, breathing also suddenly ceased at the moment of an abdominal incision during deep anæsthesia, but as there was some rigidity of the abdomen and chest, the case may possibly have been one of reflex respiratory *spasm* rather than inhibition.

The treatment of this condition is artificial respiration.

CHAPTER XIX

CIRCULATORY FAILURE

Disturbances of the peripheral circulation are exceedingly common during general surgical anæsthesia, and in a considerable proportion of the cases in which these disturbances occur there is no necessity for anxiety. It by no means follows, because the pulse has ceased at the wrist, that the heart has ceased also. Nor does it follow, because the pulse has become impalpable in one artery, that it has vanished from another.[1] Just as many of the respiratory phenomena displayed by anæsthetised patients may be misinterpreted, so may many of the circulatory phenomena be misunderstood and ascribed to causes which are not at the moment in operation. There is, perhaps, a greater liability for errors of this kind to creep in when studying the pulse than when observing the respiration; and this probably explains the existence of a doctrine which is unfortunately prevalent in many quarters, viz. that the pulse should be wholly disregarded during the administration of anæsthetics. It is urged by those from whom this doctrine emanates that any attention to the pulse may interfere with the vigilant observation of the breathing, and that, in addition to this objection, pulse-changes may actually mislead. The author cannot too strongly dissent from such teaching. As will be presently seen, there are many cases in surgical practice in which pulse indications may be of the greatest possible value; and the anæsthetist who ignores these indications is closing the door of knowledge in his own face.

[1] The author has on several occasions met with what has appeared to be local pulselessness, which he has been unable to explain, except by the assumption that local vaso-motor effects have been reflexly produced.

It is not a difficult matter for a man of average ability to occasionally feel the pulse without relaxing his attention to the breathing. Moreover, should pulse indications mislead (as they unquestionably may), it is because the anæsthetist is in ignorance of the true causes of the circulatory changes which are taking place before him. Provided there be nothing in the general state of the patient to depress the circulation; that the anæsthetic be administered only to a *moderately* deep degree —in other words, without completely abolishing the corneal reflex; and that respiration be freely performed, pulse-indications will certainly be of little or no value. In modern surgical practice, however, we often have to anæsthetise patients whose circulation is in a very unsatisfactory state; whilst it is frequently necessary to administer anæsthetics to such a degree that no corneal reflex can be allowed. It is under one or other of these circumstances that the pulse will very greatly assist us. To take the peripheral circulation as the sole or even the principal guide in the administration of an anæsthetic would be the worst possible practice; but it is here contended that to study its changes from time to time is essential if we wish to obtain the best results.

In all cases in which chloroform or a chloroform mixture is to be employed, and in which the exigencies of the operation may require a deep anæsthesia, it is a good plan to have the radial pulse within easy reach. This is particularly important when, as in abdominal operations, surgical shock may complicate the anæsthesia.

There are numerous causes upon which circulatory depression or failure during anæsthesia may depend. They are summarised in the accompanying table.

[TABLE

Tabular Summary of Causes of (Peripheral) Circulatory Failure during General Surgical Anæsthesia: with Examples

Predisposing Causes.	Examples and References.	Exciting Causes.	Examples and References.
Profound mental disturbance.	See p. 406.	1. Embarrassed or arrested breathing (Intercurrent Asphyxia).	See Illust. Cases, Nos. 51 and 52, pp. 570-71.
Anæmia, general debility, or cachexia.	See p. 163.		
Shock from injury or loss of blood.	See p. 173.	2. Overdosage by Anæsthetic producing:— (i.) Cardio-vascular paralysis, or (ii.) Cardio-inhibitory effects.	See p. 412.
Abnormally slow pulse.	See p. 171.		
Liability to "faint" (?)	See p. 567.		
Feeble, fatty, dilated, or diseased heart.	See p. 171; also Illust. Case, No. 49, p. 568.		
Grave respiratory affections attended by dyspnœa.	See p. 166.	3. Surgical procedures causing:—	
Degenerated vascular system.	See p. 172.	(i.) Surgical shock (circulatory), *i.e.* either reflex vasomotor effects or reflex cardio-inhibitory effects, or both;	See Illust. Cases, Nos. 54, 56, and 59.
Venous thrombosis.	See Illust. Case, No. 50, p. 568.		
The sitting posture.	See p. 117.		
The presence of food or fluids within the stomach.	See p. 412.	(ii.) Hæmorrhage; or	See Illust. Cases, Nos. 69 and 70.
		(iii.) Entry of air into vein.	See Illust. Case, No. 71.
		4. Change from horizontal to sitting posture during deep anæsthesia.	See p. 117.
		5. Detachment of thrombus and lodgment in cardiac valves.	See Illust. Case, No. 50, p. 568.

The various conditions which may act as predisposing causes of circulatory failure are summarised in the first column of the above table. In the second column will be found references to those parts of the work in which the influences of these conditions have been discussed. It must not be inferred from this somewhat extensive list that circulatory failure during anæsthesia is invariably attributable to one or other of the predisposing causes mentioned, or that such causes

necessarily operate prejudicially. For example, pulse failure may readily be brought about by surgical shock during deep chloroform anæsthesia, even though the patient belong to the most healthy type; whilst the presence of anæmia, with its necessarily attendant circulatory conditions, may actually safeguard the patient against circulatory depression by the susceptibility he obviously displays in the early stages of anæsthetisation. The influences of predisposing causes of circulatory failure are best seen when some strain is thrown upon the circulation by the operation of one or other of the exciting causes mentioned in the third column. Other things being equal, the more healthy and adaptable the circulation, the better will it be able to withstand any such strain to which it may be subjected, and the greater will be the chance of re-establishing normal conditions by appropriate treatment.

Profound mental disturbance rarely induces circulatory changes of any great importance. Nothing need here be added to what has been already said concerning anæmia, general debility, cachexia, and shock from injury or loss of blood. Patients with an abnormally slow pulse are undoubtedly specially liable to circulatory depression during deep chloroform anæsthesia. In some of the cases in which the author has met with sudden and acute surgical shock during chloroform anæsthesia, the patients, although apparently in good condition, have had a history of liability to "faint" from badly ventilated rooms, pain, or other causes; but it is uncertain to what extent this liability predisposes to circulatory depression. The factor of cardiac disease has already been fully considered, and an interesting case has been referred to, in which an injudicious line of treatment led to very unfavourable symptoms in a patient with morbus cordis (p. 171). Perhaps the most important of these predisposing causes is the presence of some grave respiratory condition, in the course of which cardiac embarrassment has taken place. For example, when sudden death occurs early in the chloroformisation of a patient suffering from acute pleuro-pneumonia, attended by cyanosis and dyspnœa, death is cardiac, not asphyxial, the labouring heart coming to an abrupt and final standstill as the result of the slight additional strain imposed

upon it by transient breath-holding or struggling. In less grave respiratory states, and particularly in those of a more chronic type, the circulatory failure met with during anæsthesia, although of the same nature, is not so likely to be fatal. This is well seen in the following case which has many points of interest:—

Illustrative Case, No. 49.—F., æt. 76. Short and stout. Chronic bronchitis and dilated right heart. Respiration wheezy. Fair pulse. Operation for mammary tumour. C.E.-chloroform sequence. Skinner's mask. Operation begun before corneal reflex quite lost, but no reflex movement. Very little hæmorrhage. Gradually increasing pallor and rather slow pulse. Light anæsthesia maintained. The incision was a fairly large one, and one axillary gland was removed. Operation lasted half an hour. When nearly conscious she was pale *with no wrist pulse.* It was clear that her blood was principally in the venous system. A small quantity of ether administered on a Skinner's mask. Requested her to cough. Pulse immediately returned. It was observed by operator that the axillary vein was very large during the operation.

It is clear that in this case the dilated right heart, which was only just able to maintain the pulmonary circulation when the patient was not under an anæsthetic, became temporarily incompetent to discharge its usual functions. This was probably partly owing to the effect of the anæsthetic upon its musculature (although the anæsthesia was never deep), and partly also to a somewhat increased strain caused by altered respiratory conditions.

Amongst the changes in the vascular system which predispose to cardiac arrest, that of venous thrombosis must not be forgotten. In the following interesting though highly exceptional case, a detached thrombus became entangled in the tricuspid valve during anæsthesia and caused the death of the patient (see also p. 173).

Illustrative Case, No. 50.—F., æt. 32. Wasted. Nervous. Heart-sounds rather feeble. No heart or lung disease discoverable. There had been œdema of left leg. Operation for removal of large fungating sarcoma of right breast. Ether by Clover's inhaler. Anæsthetic taken well. No cough, struggling, or cyanosis. Good pulse. Corneal reflex had just disappeared when operation began. No reflex movement on incision. Growth removed in about three minutes. Pulse suddenly became feeble and face pale. Very little bleeding at site of operation. Pulse ceased. Respiration continued for some minutes. Operation at

once stopped (15-20 minutes after commencement of administration), and every means tried to restore patient (artificial respiration, strychnine, etc.), but without success. *Post-mortem:* Rigor mortis marked. Much wasting. Pleuræ: *nil.* Lungs emphysematous: not gorged with blood: no bronchitis. Heart weighed 8 oz.: left ventricle firmly contracted and empty: right ventricle moderately contracted and containing 1 oz. of fluid blood. In right side of heart, entangled in tricuspid valve, is an ante-mortem clot, consisting of a thick portion 1 inch long, $\frac{1}{2}$ inch in diameter, and irregularly cylindrical, with three longer thinner portions from $\frac{1}{3}$ to $\frac{1}{4}$ inch in diameter, and 2 to 4 inches long (clearly formed in some vein). Pulmonary, tricuspid, and aortic valves normal. Mitral also. Partial thrombosis of left common iliac vein. Nothing else abnormal.[1]

The influences of the sitting posture and the presence of food and fluids within the stomach have been sufficiently discussed.

It will be convenient to consider the treatment of circulatory failure in relation to the exciting cause upon which the failure depends.

1. TREATMENT OF CIRCULATORY FAILURE DEPENDENT UPON EMBARRASSED OR ARRESTED BREATHING

Embarrassed breathing is a common cause of pulse-failure during anæsthesia. There is good reason, indeed, to believe that in a large number of the cases in which the first symptoms of danger observed have been disappearance of pulse and change of colour, some initial embarrassment to breathing has been overlooked. For example: a child is operated upon for the removal of post-nasal adenoid growths: the operation is successfully finished: the patient, who is beginning to "come round," is moved back to bed and placed horizontally: the breathing becomes suspended by reason of commencing vomiting (laryngeal closure), and possibly the presence of coagulated blood about the rima glottidis: cyanosis ensues: then pallor: then pulse-failure: and, unless the patient's condition be observed in time, death quickly takes place. If the surgeon be unaware of the liability of such patients to pass into this condition of asphyxial syncope, he

[1] For these notes the author is indebted to the late Dr. Schorstein and Mr. E. E. Prest. It was entirely owing to the former that the true cause of death was discovered; and Mr. Prest's notes of the administration render the case complete.

may easily overlook the asphyxial factor and erroneously attribute the fatality to one or other of the numerous causes which are believed to be capable of suddenly bringing about primary cardiac arrest. It has been pointed out in preceding parts of this work that respiration is exceedingly liable to become temporarily embarrassed during anæsthesia; and the rapidity with which the peripheral circulation will cease will depend upon the normal state of the patient's vascular system, the particular anæsthetic employed, the degree of anæsthesia, and other factors.

The treatment of all states of circulatory depression dependent upon impaired or suspended breathing is sufficiently obvious. It is to correct any respiratory embarrassment, to secure a free air-entry, and, if necessary, to perform artificial respiration in the manner fully described in the preceding chapter.

The following case may be of interest as illustrating this form of circulatory failure and the proper treatment to be adopted:—

Illustrative Case, No. 51.—A thin, middle-aged man, with spinal disease. Heart displaced by distorted spine. Apex beat in fourth space outside nipple. Marked pulsation in second left space close to sternum. Blowing systolic bruit at base. No thoracic movement. Respiration wholly diaphragmatic. Laminectomy. Left lateral posture. Ether administered by Clover's inhaler. Student administering under my supervision. No excitement. Breathing rather short and colour rather dusky. Patient now placed almost prone, with trunk somewhat raised. Operation begun. Very little bleeding. Breathing jerky: colour dusky: pulse bad. No ether given for about 10 minutes (rather more than necessary had been administered). Pulse, however, grew worse, becoming very rapid and irregular. It then ceased at wrist. Respiration continued. Colour pale and dusky. Hands cold and blue. At this point I was obliged to ask the surgeon to alter the patient's posture. He was accordingly placed upon his side, and improvement immediately commenced. The colour of face and lips now returned, *but hands remained very blue*, showing that cyanosis is not necessarily an indication that the heart is satisfactorily pumping along non-oxygenated blood. The improvement continued and the operation was completed.

In the above case the embarrassed breathing (from pre-existing intercostal paralysis and the prone posture) gradually led to pulselessness. Possibly the cardiac condition (the nature of which the author was unable to diagnose), together

with the displacement of the heart, contributed to the pulse-failure.

In the following case the intercurrent asphyxia, with consequent pulselessness, was chiefly, if not wholly, referable to faulty posture.

Illustrative Case, No. 52.—F., æt. 50. Thin. Asthmatic. Some emphysema and cough. Radical breast operation. *Pillows under shoulder, and head slightly extended.* C.E.-chloroform sequence. Considerable laryngeal stridor throughout from mucus, with ineffective cough. Mucus not expelled. With the "crowing" breathing there was much diaphragmatic movement, and hence negative pressure in chest. *Consequently radial pulse became very feeble and then impalpable.* When laryngeal stridor lessened, the pulse improved; when it increased, the pulse became weaker. These effects were noted several times. The operator also observed phases of bleeding and of no bleeding corresponding to diminished and increased stridor.

The above case might easily have been diagnosed as one of surgical shock; but it was clearly one of a different nature. Possibly some slight circulatory shock of surgical origin was present and favoured the pulse disappearance from intercurrent asphyxia.

2. TREATMENT OF CIRCULATORY FAILURE DUE TO OVERDOSAGE

We have seen that when nitrous oxide or ether is administered in toxic doses to a moderately healthy subject some impairment of breathing invariably precedes pulse-failure; whereas in the case of chloroform a noticeable degree of circulatory depression is a common accompaniment, if not a precursor of respiratory arrest. When anæsthetising patients, however, whose general condition is highly unsatisfactory, the administration of toxic quantities of any anæsthetic, whether it be nitrous oxide, ether, or chloroform, may be attended by more or less sudden and primary cessation of pulse.

The treatment to be adopted in all such conditions is to withdraw the anæsthetic, to place the patient horizontally (unless he be already so placed), and to increase respiratory action. Many a life has been sacrificed by erroneously resorting to drugs. In comparatively minor cases in which the pulse has become very slow, feeble, irregular, or intermittent,

whilst respiration is still continuing, all that is needed, as a rule, is to rub the lips briskly and to assist the feeble respiratory efforts by chest compression. These measures will often ward off a more alarming state, the pulse and colour quickly improving in response to this simple treatment.

But in most cases primary pulse disappearance from the toxic effects of an anæsthetic is such a grave symptom that vigorous measures are at once needed, and it is advisable to insert a Mason's gag, apply the tongue-forceps, extend the head over the end of the table, and proceed to Silvester's method of artificial respiration as already described. The gag and tongue-forceps are needed to maintain a free air-way; the lowering of the head is likely to be of use in keeping up the blood supply to the respiratory centre; and artificial respiration is the best cardiac stimulant.

Should there be no respiratory embarrassment or evidences of general venous engorgement, partial or complete inversion, as originally suggested by Nélaton in 1861, may be advantageously combined with artificial respiration. It is important, however, to remember that the essential treatment is the maintenance or re-establishment of efficient respiration, without which the elimination of the anæsthetic cannot take place. Many remarkable cases are on record[1] in which, by means of inversion, patients have apparently been rescued from imminent death. In some of the recorded cases the pulse at the wrist was observed to come and go as the patient was inverted or placed horizontally. It is probable that the beneficial effects of partial or complete inversion are principally due to the better respiratory action caused by an increased cerebral blood supply. Inversion should never be employed unless the signs of circulatory failure are distinctly marked.

In the event of these measures failing to resuscitate the patient, the question of directly kneading the heart should be considered.

In young subjects in whom the chest walls are resilient, there is no great difficulty in applying intermittent pressure from without,

---

[1] See *Deutsche med. Zeitung*, Feb. 1885; Braithwaite's *Retrospect*, vol. i., 1876, p. 348; *Edin. Med. Journ.* vol. ii., 1874, p. 476. Kappeler states that Schuppert saved three patients by inversion.

as in the case referred to on p. 587. In older subjects this procedure will be inapplicable, and the heart must be reached by surgical means. If the case be an abdominal one, and the abdominal cavity be open, the heart may be grasped through the diaphragm and rhythmically kneaded. This treatment was first successfully applied by Mr. W. Arbuthnot Lane in a case of syncope during the removal of the vermiform appendix.[1] If the abdominal cavity be intact when this *dernier ressort* is decided upon, it should be rapidly opened below the ensiform cartilage and the heart kneaded through the diaphragm. In 1905 Dr. H. M. Gray [2] recorded an interesting case of asphyxia in which he temporarily re-established cardiac action by "sub-diaphragmatic transperitoneal massage." In the same year Mr. T. Rudolph Smith and Dr. W. R. Daglish successfully employed this treatment in a case of chloroform syncope. Three minutes after pulse and respiration had ceased, the abdomen was opened and the ventricles gently kneaded through the diaphragm. The whole subject of direct cardiac massage or kneading has been recently studied by Lenormant.[3] According to this author, direct massage of the heart is attended by good results in lower animals. Le Fort found it impossible to make more than thirty direct compressions per minute. Of the three methods of gaining access to the heart—the sterno-costal, the abdomino-transdiaphragmatic, and the abdomino-sub-diaphragmatic—Lenormant urges the claims of the last as the least dangerous. In three-fourths of the successful cases collected by him this third method was chosen. Of twenty-five cases in which cardiac massage was employed, four completely recovered; but it is uncertain from the facts available whether these patients might not have recovered under less heroic treatment.

The great difficulty in connection with this treatment is to decide whether and at what particular moment it should be applied. Direct heart-kneading can hardly be regarded as justifiable in cases in which there is any evidence of the existence of cardiac action; for by semi-inversion and efficient artificial respiration a feebly acting heart may almost invariably be restored. Should partial inversion and effective artificial respiration fail to produce any signs of cardiac action, direct heart-kneading would seem to be indicated. Further observations, however, are necessary before anything more definite concerning this treatment can be stated.

Drugs are of little if any service in cases of this class, and if employed *should be administered, not by the anæsthetist, but by some other person present.* The anæsthetist's undivided attention must be devoted to maintaining *efficient* artificial

[1] *Lancet*, 22nd November 1902, p. 1397.
[2] *Ibid.*, 19th August 1905, p. 501.
[3] *Brit. Med. Journ.*, 28th April 1906 (Epitome), p. 62.

respiration and a proper posture. To commence the treatment of a marked case of chloroform syncope by a hypodermic injection of ether or brandy is not only useless (seeing that the circulation is more or less suspended) but dangerous, in that such a procedure delays the application of artificial respiration, the remedial measure by which the elimination of the anæsthetic and the aeration of the blood are effected, and the measure of all others which is most likely to increase cardiac action. There is, of course, no objection to the employment, by some other person than the anæsthetist, of such drugs as ammonia,[1] nitrite of amyl,[2] strychnine, or caffeine;[3] but these substances should only be used as adjuncts, and in the manner described.

It is doubtful whether faradism is of any value as a remedial measure in these cases. Professor MacWilliam[4] advises rather strong induction shocks, with the skin moistened, one electrode being placed over the heart's apex, and one over the fourth dorsal vertebra. Schäfer and Sigmund Meyer, on the other hand, consider faradism to be as likely to inhibit as to stimulate a feebly acting heart.

The worst and most fatal cases are those in which an overwhelming dose of chloroform has been given during or immediately after violent struggling. Although it is true that in cases of this kind some degree of respiratory embarrassment occurs, the prominent and appalling symptom is pallor and complete cessation of pulse. Our resources on these occasions are unfortunately very inadequate; for beyond the treatment already considered we know of no other restorative measures likely to be of service.

[1] Ringer found that ammonia restored the action of a frog's heart which had been arrested by chloroform. See *Practitioner*, vol. xxvi., 1881, p. 436. Pickering, in his experiments with the embryonic heart of a chick, also found that he could partially restore cardiac rhythm by means of ammonia.

[2] Dr. Wood's experiments with this drug led him to regard it, at all events in chloroform syncope, as valueless.

[3] This may be given subcutaneously in 2 gr. doses.

[4] "Electric Stimulation of the Heart in Man" (*Brit. Med. Journ.*, 16th Feb. 1889).

3. TREATMENT OF CIRCULATORY FAILURE DUE CHIEFLY TO THE SURGICAL PROCEDURE

(i.) General Remarks

We now come to a very important part of our subject—the treatment of cases in which primary circulatory failure takes place chiefly, if not wholly, as the result of some surgical procedure. The cases in which the manipulations of the surgeon primarily affect respiration have been discussed in the preceding chapter. The reader is referred to pp. 44 and 76 and 253 for remarks upon the surgical influences which may primarily affect the circulation of the anæsthetised subject. It will be seen from the summary in the foregoing table that such procedures may bring about circulatory failure in three main ways—by causing (i.) surgical shock of a circulatory type, *i.e.* reflex vaso-motor or cardio-inhibitory effects, or both; (ii.) hæmorrhage; or (iii.) the entry of air into veins.

It must be remembered that when circulation fails as the immediate result of the operation in hand, there is usually more than one factor responsible. Thus vaso-motor effects are often coupled with cardio-inhibitory effects. Again, cases present themselves in which circulatory failure, although principally due to hæmorrhage, is partly referable to vaso-motor or cardio-inhibitory depression. Then, as we have already seen, deep anæsthesia, and especially deep chloroform anæsthesia, is such an important predisposing cause of surgical shock of the kind now under consideration that from some points of view the anæsthetic must be regarded as a factor. As it is often necessary, however, in the practice of modern surgery to carry the administration of the anæsthetic to its full limits, and as these full limits may be reached, *in the absence of surgical stimuli*, without circulatory depression occurring, it is clear that from the point of view of the anæsthetist the anæsthetic can hardly be considered blameworthy. Finally, in addition to these factors, there are sometimes others of a respiratory character present, but these have been already considered in the preceding chapter.

(ii.) Cases Illustrating the Occurrence of Surgical Shock (Circulatory)

Before summarising the treatment of circulatory failure due chiefly to the surgical procedure it will be convenient to quote several cases illustrative of the various ways in which the circulation may become depressed or arrested as the result of vaso-motor or cardio-inhibitory impulses of surgical origin.

Illustrative Case, No. 53.—F., æt. 42. Rather thin. Not nervous. An excellent subject, not liable to faint. Good heart-sounds. No cough. Good colour. Dilatation of cervix. Nitrous oxide-C.E. sequence for 4 minutes: then chloroform. No movement or struggling from first. During first ten minutes pulse, colour, and breathing good. No reflex movement even though corneal reflex slightly present. Patient in lithotomy position (Clover's crutch). At a particular juncture, whilst the pupil was medium in size, the corneal reflex either just present or just absent, and whilst the retroverted uterus was being dilated, the pulse suddenly became irregular and disappeared, the face pale, and the breathing suspended. The eyes did not open. (Compare subsequent cases.) I at once applied rhythmic compression to the chest walls and air entered and left the lungs. The operation was allowed to proceed. As the face remained pale, and automatic breathing did not recommence, the head was lowered, and the surgeon was asked to raise the pelvis by means of a pillow. By this time (two minutes after commencement of the shock) the corneal reflex had briskly returned. The face was still pale, the respiration feeble, and there was only a small radial pulse. Some ether was administered on a Skinner's mask. The operation, which had been suspended, was recommenced. No reflex movement. C.E. mixture now used, and pulse, breathing, and colour all gradually recovered.

A few years ago the author would certainly have ascribed the symptoms in the above case wholly to chloroform. He is now convinced, however, that they were chiefly of reflex (surgical) origin, the chloroform acting merely as the predisposing factor. In this particular case the patient was being most carefully watched, and it so happened that the radial pulse was being felt when the sudden shock occurred. The rapid recovery of lid-reflex clearly shows that the case was not one of simple chloroform overdosage. This, indeed, was obvious from the general state of the patient at the moment

when the pulse failed. Another important point in the diagnosis between simple overdosage on the one hand and surgical shock during deep anæsthesia on the other, is that when the former condition is gradually produced experimentally the circulation does not suddenly cease.

In the two following cases the pulse-failure was also exceedingly abrupt, being caused, in the first case by vigorous traction upon the pectoral muscles, and in the second by pulling upon nervous structures in the neck.

Illustrative Case, No. 54.—F., æt. 35. Well nourished. Good heart-sounds. No cough. Reported to occasionally suffer from fainting attacks—"remains faint for hours." Removal of left breast. Nitrous oxide-ether-chloroform sequence. No reflex movement with incision. Ten minutes after administration had begun, the patient was deeply but satisfactorily under chloroform. The surgeon passed his finger behind the pectoral muscles and vigorously pulled them forwards with the object of dividing them. At the moment of traction the pulse became feeble; and whilst the muscles were being cut there was sudden and alarming pallor, with pulse disappearance, these symptoms being quickly followed by arrested breathing. The patient's body was quickly adjusted so that the head hung over the end of the operating table; the chest walls were compressed; and the fauces stimulated by the finger-tip. At first no effect was produced, but after 5 or 6 compressions breathing gradually recommenced. The patient soon began to "come round." Chloroform resumed and administered for rest of operation.

The points of interest in the preceding case are (1) the obvious dependence of the symptoms upon the surgical procedure; (2) the short interval between the occurrence of shock and the phenomena of recovery; and (3) the immobility of the chest wall. There was no muscular spasm such as there usually is when the chest fails to respond to compression. The gradual resumption of breathing was probably due to the better blood supply caused by lowering the head. In the following case, one of amputation of the breast, the shock was less severe. Some degree of surgical shock is exceedingly common in these operations under chloroform or chloroform mixtures.

Illustrative Case, No. 55.—F., about 61. Fat. Lives sedentary life. Radical breast operation. Induction by C.E. on Skinner and Rendle; then chloroform on Skinner. No excitement. Operation begun when patient under chloroform with trace of corneal reflex. Portion

of breast first removed for microscopic examination. No abnormal phenomena. Ten minutes later, whilst patient well under, but not too deeply under chloroform, and whilst breast being removed and a good deal of traction taking place, pulse disappeared at radial, superior coronary, and temporal arteries. Respiration appeared to be about to cease. Pallor. Cold face. No movement. Anæsthetic withheld. Corneal reflex soon returned. Changed to C.E. mixture, but condition remained about the same for 20 to 25 minutes after first shock, when pulse and colour returned. During this 20 or 25 minutes there was very little bleeding. Pulse not good till operation over.

In the above case the corneal reflex was absent when the shock came on. The author has notes of several similar cases. He also has notes of a case in which the breast was pulled away from its attachments whilst the corneal reflex was present, with the result that simple slowing of the heart took place. It is quite possible that with such stimuli during comparatively light anæsthesia, cardio-inhibitory effects, as opposed to cardio-inhibitory and vaso-motor effects combined, are most likely to be met with. (Cf. Illust. Case, No. 68.)

Deeply seated operations in the neck are not unfrequently attended by surgical shock, as the three following interesting cases testify. Unfortunately it is not always an easy matter to say what particular nerve or nerves are being dragged upon or injured at the moment when shock takes place.

Illustrative Case, No. 56.—M., æt. 35. Healthy looking. No thoracic abnormality detected. Operation for removal of deeply seated cervical glands. Nitrous oxide - ether - chloroform sequence. Smooth induction. Fifteen minutes after incision, patient being fully but not too deeply under chloroform, traction upon the glands and their surrounding structures was at its height when the eyes suddenly opened, the pupils dilated widely, and the breathing ceased. I was not observing the pulse at the time. The surgeon admitted that he might have been dragging upon the vagus. After two or three compressions of the chest there was immediate improvement in the patient's condition. The pulse at the wrist was slow. This slowness of pulse and some pallor persisted for the rest of the operation, but no further difficulties occurred.

The sudden separation of eyelids was the most remarkable feature of this case. For the moment the patient displayed a most alarming appearance, similar to that described in Illustrative Case, No. 71, in which the syncope was caused by air entering a vein.

Illustrative Case, No. 57.—M., about 35, of average build. Good general health. Not markedly nervous. Removal of sarcomatous tumour of soft palate. Chloroform. Junker's inhaler. Anæsthesia in 8 to 10 minutes. Muscular flaccidity; abolition of lid-reflex; and slight stertor. Two stages in the operation: (1) Placing a temporary ligature round the carotid artery; (2) removing growth of palate. The skin incision was unattended by movement or other phenomena. Whilst artery being exposed pulse became extremely feeble, face pale, respiration shallow, and operator had some difficulty in recognising vessel by reason of its diminution in size. Head lowered and legs raised. After three or four compressions of chest, pulse gradually improved, and rigidity and lid-reflex reappeared. Ether then given for remainder of operation.

The next day, whilst the wound over the carotid was being examined without an anæsthetic, the patient's face suddenly became pale, the artery contracted as on the previous occasion, the eyes turned up, the muscles of the jaw twitched, and for a few seconds the patient was unconscious.

I anæsthetised this patient two years later, and gave him ether for the removal of a very small recurrent nodule. No difficulty occurred. It is fair, however, to add that no ligature was placed round the carotid.

I anæsthetised this patient for a third time, just three years after the last administration. Another recurrent nodule had to be removed. I used the A.C.E.-ether-chloroform sequence, and secured a deep ether anæsthesia for the commencement and first stages of the operation. No abnormal symptoms were noted under ether; but during the subsequent chloroformisation, whilst the palate was being held, and a further portion of the growth excised, the pulse became very slow for three or four beats, and for 20-30 seconds could not be felt. The respiration was deep and regular all the time. The colour was perhaps a trifle paler. The anæsthetic was withheld, and the pulse gradually returned. Though the patient was well under chloroform at the time the pulse vanished, he was not too deeply anæsthetised, for he began to show signs of recovery half a minute after the anæsthetic had been discontinued.

Illustrative Case, No. 58.—M., æt. 60. Healthy and muscular. Florid cheeks. Iron-grey beard. Had his tongue removed some months ago. Now has epitheliomatous glands of neck requiring removal. Heart-sounds good; not nervous. Chloroform administered on Skinner's mask. Drop-bottle. No struggling. Some temporary respiratory difficulty before deeply under; easily removed by pushing jaw well forward. Fully anæsthetised in 5-6 minutes. No movement with skin incision. The signs of anæsthesia were: Regular, softly snoring breathing: no corneal reflex: fixed eyeballs: pupils $3\frac{1}{2}$ mm.: good colour. As this pupil was a trifle larger than the ordinary chloroform pupil, I instructed the student who was administering the chloroform to somewhat lessen the amount of anæsthetic. This brought the pupil to $2\frac{1}{2}$ mm. in about half a minute. Other signs as before. A few minutes later, during the manipulations of the surgeon for the removal of the glands (which were intimately connected with the carotid, jugular, vagus, and phrenic), the patient

became pale, and his jaw muscles flaccid. In a few seconds from this his breathing became irregular and shallow. No sound of obstruction. Respiration assisted by pressing with each expiratory effort upon the lower part of thorax. The pulse, which had not been observed before, was barely perceptible and slow. (It had probably ceased altogether when the pallor came on.) Lid-reflex now returned, and some moaning. Carotid and jugular both ligatured and glands completely and successfully removed. The operation was never suspended, as no further remedy besides chest-compression was necessary. A comparatively light anæsthesia was kept up for the rest of operation. Any attempt to abolish lid-reflex was at once followed by feeble breathing. The colour and pulse improved after the chest-compression; but patient remained pale, and with rather slow and weak but regular pulse till end of operation. Administration lasted fifty minutes. 14 dr. of chloroform used.

The patient referred to in Case 57 was apparently specially susceptible to reflex cardiac inhibition. During the second operation, in which ether was employed, and during the first part of the third operation, which was also conducted under this anæsthetic, no surgical shock occurred. But in the first operation, and in the latter part of the third operation, on both of which occasions chloroform was being used, reflex circulatory depression ensued. It is interesting, too, that a similar condition was noted in the absence of anæsthesia. In this case, as in many others, the stimulation produced by ether seems to have prevented the inhibitory effects of the surgical procedure.

Intra-abdominal operations are particularly likely to be attended by surgical shock of a circulatory type; and as such shock is favoured by deep chloroform anæsthesia, the symptoms are often erroneously ascribed to the latter condition. The five following cases are typical of many others.

Illustrative Case, No. 59.—F., æt. 42. Good colour. Rather grey. General condition good. Operation for gastric ulcer (abdominal section). Administration lasted about seventy minutes. Chloroform, Skinner's mask. No difficulty in induction. No reflex movement with incision. First part of operation consisted in pulling down stomach and plugging several large sponges into abdominal cavity. During this the lips became pale, the pulse small and slow, but the breathing was unaffected. (No corneal reflex present.) Difficult to say whether circulatory symptoms due to chloroform, to operation, or to both factors. No chloroform given for several minutes, during which there was no corneal reflex. Pulse and colour gradually improved, but by this time the dragging on stomach and

insertion of sponges had ceased and the stomach had been opened. No further trouble for next forty minutes. At end of this time, *when I was perfectly sure the patient was not too deeply under chloroform, and not too lightly*, it became necessary to remove sponges; and the patient again displayed similar symptoms to those previously noted. Clearly a reflex effect.

Illustrative Case, No. 60.—F., about 42. Not nervous. Good but rapid heart-sounds. Fair chest expansion. Said to have had pleurisy four times and to be a "fainty" subject. Removal of vermiform appendix and ovary. Operation at 8.30 A.M. Foggy and raw morning. Nitrous oxide-ether-chloroform sequence. No difficulty. Ten minutes after beginning of operation there was a trace of corneal reflex, which was permitted to remain for ten minutes, there being no reflex movement during this time. The bowel was now pulled out through wound and, *although no more anæsthetic was given*, the corneal reflex vanished. Simultaneously with pulling out bowel and disappearance of corneal reflex, there were sudden pallor and suspension of breathing, with moderate dilatation of pupils. Operation not discontinued. Face and lips briskly rubbed and respiration recommenced. No further difficulty, but C.E. substituted for chloroform owing to rather unsatisfactory pulse. Breathing remained shallow.

Illustrative Case, No. 61.—F., æt. 50. Grey. Stout. Somewhat bronchitic. Fairly good heart-sounds. Had a "fainting-fit" during use of enema before operation. Is said to have "exaggerated reflexes." Ovariotomy. C.E. gradually given on Skinner's mask, then on Rendle's. Slight cough. No difficulty. Ready in 8 to 9 minutes. No reflex movement with incision. Seven or 8 minutes later, after contents of cyst evacuated, and when empty cyst was being pulled up towards diaphragm, pulse (which had been about 70 and regular) became very slow, irregular, and barely perceptible. Face at first little if at all altered in colour. The patient was just well under C.E.—not too deeply. Anæsthetic withheld. Breathing became quieter. Surgical manipulations continued. *In about 45 seconds there was observed a peculiar batch of about 7 or 8 deep respirations, immediately followed by pallor, arrested breathing, upturning of lids, and dilatation of pupils.* Whilst proceeding to bring head over end of operating table, breathing recommenced and colour began to return, so that it was unnecessary to do anything in the way of treatment. The corneal reflex had by this time returned. There seemed to be a deepening of anæsthesia as the result of the shock.

Illustrative Case, No. 62.—M., middle-aged; 6 ft. 2½ in. Flat, badly developed chest. (?) Old adenoids. Imperfect nasal breathing. Removal of appendix. Small dental prop between teeth. Nitrous oxide-ether-chloroform sequence for 6 minutes; then C.E. mixture. Whilst appendix being pulled up, and patient *only just well under C.E. mixture*, the pulse disappeared at the temple, the face became pale, the lips separated, the pupils dilated, and the breathing ceased. These symptoms occurred in the order named, and within about 20 seconds. The chest was compressed, and the mattress slid lengthwise upon the table, so that the patient's head

became fully extended over the end of the table. After about 15 seconds, during which the chest pressure was continued, the colour improved and the breathing returned. No further difficulty.

Illustrative Case, No. 63.—F., about 35. Thin. Good type of subject. Abdominal section. Nitrous oxide-ether-chloroform sequence for induction: then C.E. Operation begun under C.E. No reflex movement. Pulse about 90 to 100. Good breathing. Whilst appendix being manipulated and patient just well under C.E. mixture, the pulse suddenly dropped in rate, respiration being unaffected. In a minute or two respiration began to lessen in force. Patient horizontal. Very little anæsthetic required. The pulse remained slow and small, the breathing shallow, and the face pale. The patient now placed in the Trendelenburg posture, with immediate improvement of colour, breathing, and pulse.

In Cases 60 and 61 the most interesting point is the deepening of the anæsthesia as the apparent result of the surgical shock. The author would also specially direct attention to the curious batch of deep respirations observed in Case 61. He has seen this phenomenon in other cases immediately before cessation of breathing from suspended cerebral circulation. In Case 63 cardiac inhibition was a marked result of the surgical interference, and the beneficial effects of the Trendelenburg posture are well exemplified.

Rectal operations are frequently attended by slight circulatory shock, even though ether be employed. The following case may be regarded as typical.

Illustrative Case, No. 64.—M., about 55. Tall. Thin. Has a beard. Said to have a "weak heart," but sounds fairly good. Slow action. Operation for hæmorrhoids. Nitrous oxide-ether sequence followed by C.E. mixture. No difficulty. Rectal dilatation begun when patient fairly well under C.E. Slight reflex movement and "crowing" breathing. After ten minutes the pulse became very slow and the face pale. There was slight corneal reflex present. No reflex movement. Pulse became slower and disappeared at temple. Breathing fair. Ether given on Skinner's mask. Corneal reflex became brisk. No reflex movement. Pulse gradually returned, but never became full.

This was a clear case of cardiac inhibition during moderate C.E. anæsthesia. The absence of reflex movement during the period of shock, when the patient was very lightly under the anæsthetic, is of interest.

In the following case the surgical shock was much more severe. It is of interest, because no special remedial measures were employed, and yet the patient made a good recovery.

Illustrative Case, No. 65.—F., about 57. Thin. Slight bronchial catarrh. Said to be liable to faint. First stage of Kraske's operation. C.E. given gradually. No excitement. When anæsthesia nearly complete patient placed nearly prone, with raised buttocks and knees below level of table and resting on chair. Pulse quick—about 110. Breathing somewhat hampered by posture. Slight corneal reflex maintained. Very slight movement with incision. During sawing of bone, whilst corneal reflex only just absent, pulse suddenly disappeared, face became pale and dusky, and hands cold. The head was brought to the side of operating table and the anæsthetic discontinued. Corneal reflex soon reappeared. From this point onwards no anæsthetic given beyond a little ether occasionally. Operation not stopped. Still no pulse, but breathing continued feebly. One shoulder raised in order to relieve respiration. *No pulse at wrist for* 20 *minutes.* Operation rapidly completed. Brisk corneal reflex. When flaps brought together pulse began to reappear and breathing became deeper. Gradual recovery. When legs placed horizontally pulse at once improved. When patient moved to bed, and end of bed much raised, further distinct improvement in pulse observed, with warm hands, better colour, and restoration of consciousness.

Three days later patient's condition quite as good as before first operation. Second half of operation now necessary. Excision of rectum. Quick pulse. C.E. for 50 minutes : ether 20 minutes : C.E. again for 25 minutes. After 10 minutes' anæsthesia patient placed in prone-Trendelenburg posture (p. 243). During first 50 minutes much reflex laryngeal stridor (?) from peritoneal traction. Stridor stopped by changing to ether. No shock for first 25 or 30 minutes. Then increasingly rapid pulse : cold hands and forehead : and pulse nearly imperceptible. Respiration good. Shock never alarming. Pulse rather better when wound closed, but difficult to count. Distinct improvement when patient placed horizontally, owing to better chest expansion.

The acute surgical shock in the first of these two operations occurred during properly established C.E. anæsthesia. It was obviously not due to hæmorrhage, as evidenced by the quick and good recovery, nor was it due to the anæsthetic, for reasons already given. It was, in fact, of that type specially discussed by Crile (p. 77), and was probably chiefly of vasomotor origin.

Operations upon the kidney, particularly if associated with traction upon that organ, frequently cause intercurrent surgical shock.

Illustrative Case, No. 66.—Healthy-looking child, about 5 years of age. Nephrectomy for sarcoma of kidney. Chloroform on Skinner's mask administered by a student under my supervision. All went well till fifteen minutes after the commencement of the operation, when, during the manipulations of the surgeon, the following events occurred in the

order mentioned. (1) The pulse became very slow, the respiration being regular and the colour good. The anæsthetic was withheld. (2) The pulse became slower and feebler, and the respiration almost imperceptible, whilst the lips remained of good colour. (3) The radial pulse ceased and the colour became dusky. Inversion and artificial respiration very quickly restored the circulation.

Illustrative Case, No. 67.—F., æt. about 35. Very anæmic from long-standing hæmaturia. Short stature and spare build. Pulse 84, regular and extremely compressible. No respiratory difficulty. Nephrectomy for renal tumour. Time, 10.40 A.M. Administration commenced with A.C.E. mixture on Skinner's mask. At 10.42 respiration rather rapid—suggestive of hysteria. 10.43, Ormsby's inhaler, charged with ether, gradually applied. Deep anæsthesia rapidly produced. Pulse fair, but quicker than before commencement. Patient lying on side with pillow under loin : head low : face towards bed. Respiration regular, and not hampered. 10.52, operation begun. No reflex movement. At 11, whilst pedicle was being tied, distinct evidences of shock began to manifest themselves. Pulse rapid and feeble. Allowed patient to regain conjunctival reflex to a slight extent. Respiration regular and snoring. Pulse soon became barely perceptible at wrist. Hands warm. Fair colour. Respiration less deep and non-stertorous. As pulse now almost imperceptible, operation rapidly completed. Whilst the patient was in this condition the breathing was suddenly "held," as if straining or coughing were imminent. As the suspended respiration persisted, the sternum was pressed five or six times, and air was heard to enter and leave the chest. Automatic breathing then returned and continued, though with occasional pauses. End of table raised. Operation completed. Patient's condition gradually improved. Fifteen minutes after operation the pulse could be counted at wrist. Patient moved to bed and kept very warm. No vomiting. Made a good recovery.

Nephrectomy in a feeble and very anæmic patient is liable to be attended by shock, and, as the above case shows, the resources of the administrator may be severely taxed. That the symptoms were not due to loss of blood is perfectly certain, seeing that every care was taken, and with the most perfect success, to avoid unnecessary hæmorrhage. Nor was the anæsthetic to blame, for the symptoms in no way corresponded to those dependent upon an overdose of ether. The author has notes of several other cases of nephrectomy in which profound surgical shock (coming on independently of hæmorrhage) has occurred. In one instance yawning was a prominent symptom and the wrist pulse vanished. The patient, however, made a good recovery.

In the following case reflex cardiac inhibition took place

as the result of the skin incision for a Syme's amputation, the patient being at the time lightly under ether.

Illustrative Case, No. 68.—M., æt. about 18. Thin: breathless on slight exertion: has some dullness at bases of lungs. Syme's amputation for sarcoma of foot. Administration commenced with a small quantity of the A.C.E. mixture on Skinner's mask. Then pure ether from a Clover's portable inhaler. Patient breathed well at first; but soon commenced to give some trouble. The upper lids became raised, and it was difficult to secure tranquil anæsthesia. The lid-reflex persisted, and also some muscular movements, for about 10 minutes. Breathing somewhat hampered. Whilst in this condition the operation was commenced. It so happened that I had my finger upon the radial pulse, and that the student who was administering the ether under my supervision had his finger upon the carotid artery. The pulse was good but quick. At the moment the skin incision was made, the pulse suddenly ceased both at the wrist and at the neck, and remained absent for (?) four or five seconds. No loss of colour. Pulse resumed its previous character. Some movement of patient, showing he was not deeply anæsthetised. Attempted to secure a better and more profound anæsthesia, but respiration tended to become feeble and face pale. No further trouble during rest of operation. This patient died some weeks later, and at the autopsy a large mediastinal (sarcomatous) tumour was discovered. This had probably caused the respiratory difficulties in the administration.

Cardio-inhibitory effects under ether are very rarely met with. There is a great contrast between the inhibition phenomena of this case and those observed in deep chloroform anæsthesia.[1]

(iii.) Cases Illustrating the Occurrence of Hæmorrhage

The two following cases illustrate the effects of profuse hæmorrhage upon the circulation of the anæsthetised patient. In Case 69, the patient was at the time of operation considerably depressed by purgation, and this may have had some influence in the causation of the symptoms.

Illustrative Case, No. 69.—F., æt. 60. Rather stout; not very strong. Fair chest expansion. Heart-sounds rather distant. No winter cough. Had one ounce of castor-oil the night before operation. Three

[1] Although this case occurred many years ago, the author believes it to be worthy of a place in this edition. The method of anæsthetisation when viewed by the light of our present knowledge is certainly open to criticism.

actions of bowels. Operation 8.30 A.M. for removal of left upper jaw for sarcomatous growth. "Gas and ether" given. Deep ether anæsthesia soon came on. Operation commenced after five minutes of ether anæsthesia. Head on side, with right cheek on pillow, and face turned towards floor. Operation begun. No embarrassment to breathing from blood, as all drained into, and then out of, right cheek. As effects of ether passed off, anæsthesia kept up by chloroform from a Skinner's mask. Very profuse hæmorrhage. Less anæsthetic given. Respiration quite regular. Pulse not observed. Head always kept low. Conjunctival reflex just present. As the hæmorrhage continued to be free, I attempted to feel pulse, but could not detect one at either wrist. Hands quite warm. Respiration proceeding regularly. Lion forceps now applied and jaw removed. Very little hæmorrhage, probably from feeble circulation. Sutures rapidly inserted, and operation finished. Respiration still regular, but occasionally feeble. Still no pulse. Half an ounce of brandy, with some water, given per rectum ; a subcutaneous injection of ether administered,[1] and ammonia applied to nostrils. No effect produced. Respiration could be kept proceeding satisfactorily so long as the lips were occasionally briskly rubbed with a towel (see pp. 328, 420, and 555). Lips pale, but pinkish. Ears and cheeks pale. The wrist pulse remained absent for 20 or 25 minutes, and then gradually returned. Head kept low. Hot cloths applied to head. Even when the patient became half-conscious, the wrist pulse was barely perceptible. The patient made an excellent recovery.

Illustrative Case, No. 70.—F., 24. Thin. Healthy-looking from open-air treatment. Has had several operations for fæcal fistula. Good heart-sounds. Occasionally becomes "blue" on exertion, with a pulse of 140. No pulmonary symptoms. Abdominal section. Nitrous oxide-ether-chloroform sequence. Easily affected by nitrous oxide (suggestive of anæmia). Posture slightly on left side. Nothing abnormal for first hour except quick pulse and breathing. Pulse, 140-150. Respiration, 40-45. Good colour. Colon and ileum exposed. Rather free hæmorrhage. Kept her as lightly under as was compatible with quietude. Respiration always good. Hæmorrhage still noticeable. After one and a half hours, pulse very rapid—about 200. Eyelids closed. Hands became rather dusky. Less anæsthetic. Face pale. Vomited once. Warned operator as to patient's state. Hot coffee and brandy *per rectum.* Corneal reflex allowed to return ; *but condition did not improve.* Pulse never became slower. It became necessary to finish operation quickly and return patient to bed. She soon began to come round. Pulse difficult to count. Hands cold. Lips pale, but pink on rubbing. 10 oz. of saline per rectum and end of bed raised. 1 hour later, hands warm and skin acting. Pulse, 154 : regular.

---

[1] This we now know to be of little or no value.

(iv.) Case Illustrating the Entry of Air into a Vein

The most profound syncope that the author ever witnessed during anæsthesia came about as the immediate result of air entering a vein. The following are the notes of the case :—

Illustrative Case, No. 71.—F., 14. Florid and fairly well-nourished. Removal of cervical glands. "Gas and ether" followed by chloroform. Whilst the operator was working in the supra-clavicular region, a small quantity of air was heard to enter a vein. This was followed by rapid pulse and some pallor. A minute or two later, whilst I was carefully feeling the superior coronary artery and watching the patient, who was well under, but not too deeply under chloroform, there was a very distinct sound as of a considerable quantity of air entering a vein. The pulse suddenly vanished at the superior coronary and radial arteries; the face became deadly pale; the lids separated; the eyes became glassy; and the breathing barely perceptible. There were, in fact, all the appearances of death. I immediately lowered the head and raised the legs, and as the chest walls were remarkably elastic and yielding, and the abdomen relaxed, I was able, with my hands, to encircle the heart to such an extent that rhythmic compression of that organ became possible. The intermittent squeezing movements thus brought to bear also had the effect of forcing air into and out of the chest. At the end of three or four minutes signs of returning animation began to appear, and with the assistance of other restorative measures (strychnine, a brandy enema, warmth, etc.) the patient recovered.

It is highly probable that in the above case the patient's life was saved by cardiac compression.

(v.) Diagnosis

A few words may here be said as to the differential diagnosis between surgical shock during deep anæsthesia on the one hand, and simple overdosage on the other. The first point to be brought forward in favour of the contention that surgical shock in deep anæsthesia constitutes a frequent and readily recognisable condition is to be found in the fact that a striking similarity will be observed between many of the foregoing illustrative cases. In minor examples of surgical shock it may be difficult, or even impossible, to make a satisfactory diagnosis, but the following points will usually assist in the differentiation :—(1) Surgical (circulatory) shock

is common in certain operations and at certain stages of such operations, whilst it is uncommon and perhaps unknown in connection with other operations; (2) Although more common under chloroform than under ether, surgical shock may occur under the latter anæsthetic; (3) Acute surgical shock, although often alarming, is usually transient, a few compressions of the chest and lowering the head sufficing to restore the patient; (4) The arrest of breathing due to acute surgical shock is often immediately preceded by a few abnormally deep respirations (see Illust. Case, No. 61); (5) The re-establishment of corneal reflex takes place more quickly in circulatory failure of traumatic origin than in circulatory failure from simple chloroform overdosage.

The diagnosis between surgical shock on the one hand, and hæmorrhage on the other, has been discussed in Chap. VIII. (p. 251).

(vi.) **Treatment**

It now remains to briefly summarise the treatment of circulatory failure due chiefly to the surgical procedure. This may be discussed under two heads—preventive and immediate.

The **preventive treatment** of this form of circulatory failure is of greater importance perhaps than the immediate treatment. In cases in which surgical shock is likely to arise, special precautionary measures should be adopted, particularly when dealing with feeble subjects. Violent purgation should be avoided; the room kept warm; the bodily heat maintained by woollen clothing, and, if necessary, by a hot-water bed; the surface of the body exposed as little as possible; and all undue delay both in anæsthetisation and in operation avoided. In very feeble subjects an enema of beef-tea and brandy may be given half an hour before the operation. Careful attention to posture is advisable (p. 251). As already mentioned, shock may, to all intents and purposes, be prevented by the use of the Trendelenburg posture. As regards the best anæsthetic to be employed, there can be no doubt whatever that surgical shock is distinctly less common under ether than under chloroform or chloroform mixtures. But if ether be inadmissible, the C.E. mixture should be used rather than chloroform itself.

The most important precautionary measure, however, is the regulation of the depth of anæsthesia. All clinical evidence goes to show that grave circulatory shock is almost exclusively met with in deep anæsthesia. If the operation be of such a nature that shock is likely to arise, the depth of anæsthesia should, if possible, be lessened just before the critical point. Clinical evidence seems to indicate that the surgical stimuli which are capable of producing an acute and possibly an alarming state during deep anæsthesia, produce only a slight, and possibly only a temporary cardio-inhibitory effect when the anæsthesia is light. The occurrence, or non-occurrence, of surgical shock depends, in fact, largely upon the anæsthetist.

The **immediate treatment** of this form of circulatory failure must depend upon the degree and nature of the depression. If sitting, or semi-recumbent, the patient should be brought into the horizontal position. If the anæsthesia be deep when the shock declares itself, the anæsthetic should be withheld in order to lessen the depth. The general rule may be laid down—the greater the shock the lighter should be the anæsthesia. It is an interesting fact that when some degree of circulatory shock is present, the corneal reflex may generally be allowed to persist without the patient displaying any inconvenient recovery phenomena. In minor cases there is usually no need for anything more than lip and face friction, the maintenance of free respiration, and a reduction in the depth of anæsthesia. It must be remembered that surgical shock often is, so to speak, a conservative process, limiting hæmorrhage and rendering deep narcosis unnecessary. It may, in fact, be of questionable benefit to the patient to correct a minor degree of this condition. In acute cases, however, in which the pulse suddenly disappears, treatment must, of course, be promptly applied, the head being lowered and the chest rhythmically compressed, as in the illustrative cases above cited. If the shock be very acute, it may be necessary to resort to formal artificial respiration for a short time, or even to combine this with partial inversion. Directly the peripheral circulation has become restored, and signs of recovery have begun to show themselves, the anæsthetic may be resumed, a change from chloroform to the C.E. mixture, or

from the latter to ether, being effected if the circumstances seem to indicate such a course. It is exceptional for true circulatory shock to persist after recovery of vaso-motor control has been brought about by the simple measures above described. Should it do so it may be necessary to complete the operation with the patient in the Trendelenburg posture, or to supplement the above treatment by the administration of saline fluid (*vide infra*).

In practice true circulatory shock is often complicated by the effects of hæmorrhage or other intercurrent conditions, and it is in such cases as these that treatment other than that above described may be of value. Thus, benefit may often be derived from the use of saline infusions or injections; whilst in prolonged or desperate cases the administration of certain drugs and the application of tight bandages to the abdomen and extremities may be indicated. Strictly speaking, cases requiring treatment of this kind belong rather to the province of the surgeon than to that of the anæsthetist.

Saline fluid may be introduced as an intravenous infusion, an intra-abdominal infusion, a rectal injection, or a subcutaneous injection.[1] Crile found that the intravenous infusion of saline fluid raised the blood-pressure in all stages of shock, but, as Mummery points out, the use of saline injections does not combat the cause of the fall in blood-pressure, *i.e.* the loss of peripheral resistance in the circulation. Crile observed that after the introduction of about 320 c.c. of fluid per kilo body weight, œdema resulted. Saline infusion counteracts the tendency of the blood to become thickened by reducing its specific gravity. A sharp metal cannula, carefully sterilised, should be employed and pushed through the skin and vein-wall in a direction towards the heart. The cannula may be left in the vein ready for re-infusion. The fluid employed should consist of a sterilised salt solution 2 drachms to the pint, 3° above body temperature. One pint at a time may be slowly infused. If the operation be an abdominal one an intra-abdominal infusion of physiological salt solution at a temperature of 104°-108° F. may be introduced immediately before the wound is closed. Rectal injections have the disadvantage of comparatively slow action. They are, however, of great value as being readily applicable.

Much discussion has taken place on the use of **Strychnine.** Crile and Mummery, in their respective researches, agree that it is practically useless. The former writer found that repeated injections of strychnine

[1] See Mr. Lockhart Mummery's lectures on "Surgical Shock," *Lancet*, 18th March 1905, p. 698.

brought about, in a normal animal, a condition comparable to shock. In animals suffering from shock, strychnine only produced an effect if the shock were slight. Animals passed into a deeper degree of shock as soon as the effects of the drug had passed off.

The effects of **alcohol** have also been much discussed. Crile found that in a normal animal the intravenous injection of alcohol generally caused a fall in blood-pressure, and that in an animal suffering from shock the blood-pressure was still further lowered by this agent. Mummery corroborates this view by observations with the sphygmomanometer. In the course of a recent research Wood and Hoyt[1] have studied the physiological action of alcohol. According to these writers it increases arterial pressure when the general vascular system has been separated from its dominant vaso-motor centres; it stimulates the action of the isolated reptilian heart; and it lowers blood-pressure by dilating arterioles. The stimulant cardiac effect is thus neutralised by the vaso-dilator effect, and little or no alteration in blood-pressure takes place.

Adrenalin has been found to be useful in cases of this class. It acts directly upon the vessel walls, causing constriction, and so raises blood-pressure. Subcutaneously administered it produces little or no effect. It should be given by intravenous infusion in solutions having the strength of 1 in 20,000,[2] and as the effect is transient the infusion should be frequently repeated. The drug is most conveniently obtained as hemisine soloids. It is hardly necessary to add that the use of adrenalin is only likely to be called for in the most severe and threatening cases of surgical shock, and that if the patient's condition is such that other measures have failed there will be but little chance of success even with this powerful drug.

Ergot, which has the advantage that it may be administered subcutaneously, appears to be uncertain in its action. In some experiments upon cats, however, in which its effects were observed by Mummery[3] it markedly raised blood-pressure which had been reduced by shock. Aseptic ergot was employed, 2 gm. of the drug being diluted with 20 c.c. of normal salt solution, of which from 5 to 10 c.c. were injected at a time into the jugular vein. Unlike ergot, **ergotin** produced only a temporary effect.

At the termination of operations which have been attended by severe shock the application of a **tight binder** to the abdomen, or of bandages to the extremities, has been found useful. Crile has employed a "pneumatic suit," by means of which he has found it possible to raise the blood-pressure in such cases.

In cases in which hæmorrhage has been free, numerous important structures have been divided, and large cutaneous or cut surfaces have been exposed for a considerable time, the anæsthetist may be consulted as to the propriety of

[1] *Brit. Med. Journ.*, 17th February 1906.
[2] See a letter by Mr. Lockhart Mummery, *Lancet*, 17th March 1906, p. 790.
[3] *Lancet*, 1st April 1905, p. 850.

discontinuing the operation. Speaking generally, it may be said that the procedure of the surgeon may be permitted to proceed so long as the pulse can be counted at the wrist. If it be difficult or impossible to count the pulse, no time should be lost, as a general rule, in removing the patient to bed and in applying suitable restorative measures. These remarks do not apply to cases of acute circulatory shock, in some of which (*e.g.* Illust. Case, No. 65) it may be necessary to rapidly complete the operation, even though the patient be pulseless.

4 AND 5. TREATMENT OF CIRCULATORY FAILURE DUE TO OTHER CAUSES

Reference has already been made to the risks of raising a patient deeply under chloroform from the Trendelenburg to the horizontal, or from the latter to the sitting posture. The treatment of syncope thus arising is sufficiently obvious. Unfortunately nothing is likely to be of any service in the treatment of syncope caused by the lodgment of a detached thrombus in the cardiac valves.

PART V

THE CONDITION OF THE PATIENT AFTER THE ADMINISTRATION

CHAPTER XX

THE AFTER-CONDITION OF THE PATIENT

We have seen, in considering the after-effects of each anæsthetic, that, when the administration is discontinued and fresh air admitted to the lungs, a kind of **retrogression** in the patient's symptoms commences. A true retrogression is rarely if ever observed—that is to say, a patient rarely if ever displays, in reverse order, precisely the same symptoms which occurred whilst he was passing under the influence of the anæsthetic. With nitrous oxide, nitrous oxide and oxygen, ethyl chloride, and similar agents, **recovery** from anæsthesia quickly takes place, consciousness frequently becoming completely re-established in from 30 to 60 seconds after the administration has ceased. With agents of this kind the length of the recovery period is only to a very slight extent dependent upon the length of the administration period. With anæsthetics such as ether, chloroform, and the C.E. mixture, however, there is a distinct and direct relation between these two periods, prolonged anæsthetisation being followed by prolonged recovery, and *vice versa*. But whether the anæsthetic be one like nitrous oxide, which is rapidly eliminated, or one like chloroform, which after a protracted administration is slowly eliminated, the rapidity of recovery will largely depend upon the freedom with which lung ventilation takes place at the conclusion of the administration. For example, should some obstructive condition be present whilst a patient is recovering from nitrous oxide, consciousness may not be regained for several minutes; whereas a prolonged administration of chloroform may be followed by an unusually rapid recovery, if respiratory action be unusually vigorous. In

ordinary surgical practice the first change usually observed after the withdrawal of the anæsthetic is quieter breathing and a lessening of stertor, if present. The next sign of recovery is usually the reappearance of the lid-reflex. Deglutition movements sometimes occur first. If the patient be left undisturbed, the pupil generally grows smaller; but dilatation may occur, more especially if the patient be disturbed, or the operation be still in progress. Dilatation may also be met with prior to vomiting. The globes now commence to move from their fixed positions; the breathing becomes intermittently obstructed, from the temporary laryngeal closure incidental to swallowing; expiratory phonation and inspiratory crowing may be heard; and coughing, retching, or actual vomiting may then follow.

Towards the conclusion of an operation the bed prepared for the patient should be warmed by means of **hot-water bottles**; but the bottles should always be removed from the bed before the patient is placed in it.

It is an excellent practice, when circumstances permit, to **turn the patient well upon his side** when he is put back to bed. This is the posture which Dr. Bowles [1] so strongly recommends in apoplectic seizures. In this position stertor generally ceases; the tongue gravitates to the side of the mouth; a free air-way is established; mucus and saliva are not swallowed; and should vomiting occur, any vomited matter will readily find an escape without interfering with breathing. If the patient's head be allowed to remain in the mid-line, and more especially if his chin be permitted to rest more or less upon his sternum, breathing cannot take place freely, and recovery will therefore be tardy and unsatisfactory. Patients who have secreted much mucus, and those whose air-passages contain blood or vomited fluids, should invariably be made to clear their upper air-tract by coughing or vomiting immediately after the operation has ceased. This may usually be done by inserting a Mason's gag and tickling the fauces with the finger or tongue-forceps, the ejected fluids being removed by repeated sponging. Apart from cases of this kind, however, it is a good plan in all patients of muscular build and accurately-meeting

[1] *Stertor and Apoplexy.*

teeth to insert a Mason's gag just before recovery begins, and to keep it in position till the recovery period is well advanced. Neglect of this precaution may involve the anæsthetist in considerable difficulties at the moment when such a patient, with clenched jaws and perhaps an inadequate air-way, is attempting to eject quantities of viscid and frothy mucus through a temporarily closed channel. Those who have not had to deal with the intense jaw spasm of such subjects cannot form any idea of the difficulty that may possibly attend the maintenance of a free air-way during the recovery period.

If it be necessary to **transfer** the recovering patient from one spot to another, care must be taken to avoid the respiratory difficulties which, as already mentioned (p. 246), may attend such transference. When the bed prepared for the reception of the patient is in the room in which the operation has taken place, there is no objection to his being moved whilst still in a state of deep anæsthesia, but when he has to be transferred to another room he should have passed through the stage of coughing and retching before the transference is effected.

It is important that **the administrator should stay by his patient** till some semi-voluntary action has taken place. The following case illustrates the importance of carefully watching patients after anæsthesia, and the ease with which mistakes as to the causes and nature of symptoms may arise.

Illustrative Case, No. 72.—M., about 45. Good condition. Excision of rectum. Nitrous oxide-ether sequence. When operation, which lasted one hour and a quarter, was over, the pulse was regular, but rather weak and collapsing in quality, and the face pale. There had been rather free hæmorrhage. Some mucous râle audible. During the temporary suspension of breathing incidental to the dislodgment of this mucus by cough, the wrist pulse almost vanished and the patient's aspect became somewhat alarming. Had one not realised the presence of an asphyxial element, one might have attributed the circulatory failure to fresh hæmorrhage. Mouth opened; cough excited, and much mucus sponged out. Immediate improvement in pulse and colour.

It is not advisable to administer an **opiate** after an operation till the patient has shown distinct signs of recovery; and this particularly applies to all cases in which any respiratory embarrassment is present.

Pallor and feebleness of pulse are not uncommon after the administration of anæsthetics, but such symptoms very rarely indicate the existence of a dangerous degree of circulatory depression. They are naturally more common in feeble and bad subjects and in those who have displayed symptoms of surgical shock or of hæmorrhage than in other patients. The commonest cause of temporary circulatory failure at this stage is the respiratory embarrassment incidental to recovery. Sometimes pallor and pulse feebleness seem to arise in connection with vomiting, although the act of vomiting never takes place. On other occasions, as in the case referred to on p. 321, in which nitrous oxide was the anæsthetic used, the faintness would seem to be of traumatic (reflex) origin. In other cases again, the sitting posture is doubtless a contributory factor. Whatever the cause of such symptoms may be, it is always advisable, if the patient be sitting or semi-recumbent, that he should at once be placed in the lateral posture, his lips and face briskly rubbed with a towel, and free respiratory action encouraged. When the pulse depression seems to be connected with approaching vomiting and the patient is still unconscious, it is a good plan to tickle the fauces, the coughing or vomiting thus excited being quickly followed by a better pulse and colour. As a general rule no other treatment than this will be necessary unless, of course, the patient be suffering from surgical shock or hæmorrhage, in which case the remedial measures already advocated for these conditions must be applied.

The **room** in which the patient is recovering should be kept quiet and dark in order to encourage natural sleep.

After the use of ether or chloroform for a surgical operation, no **nourishment** should be given by the mouth for about four hours, and if at the expiration of this period the patient be disinclined for food, he should be allowed to continue his fast till this disinclination has passed away. Some clear soup or broth may then be given. Properly made beef-tea, to which a small quantity of a reliable meat extract has been added, will be found to answer well. Some patients prefer solid Brand's Essence to any liquid nourishment. After short administrations some tea or coffee with dry toast may be

permitted. If there be much thirst, sips of water, hot or cold, may be allowed as a preliminary to liquid nourishment.

As the prevention and treatment of **nausea, retching, and vomiting** are matters of considerable importance, not only to the patient but to the surgeon, a few remarks, in addition to those already made concerning their causation, may not be out of place. It may be premised that the single act of vomiting which often takes place just before consciousness returns is usually an advantage rather than a disadvantage, for it clears the air-passages of mucus, and the stomach of bilious or other fluids which would otherwise remain in that viscus, to be ejected at a less opportune moment. It is the vomiting of consciousness which here concerns us—that which disturbs the patient and in certain cases prejudicially affects the success of the operation. In the first place, the preparation of the patient, which has already been fully discussed, is of paramount importance. Secondly, the choice of the anæsthetic has its influence. We have already seen that of all anæsthetics nitrous oxide is least likely to be followed by the after-effects in question; that the administration of ethyl chloride is more often attended by gastric disturbances than is generally supposed; that transient retching and vomiting are more common after ether than after chloroform; but that persistent and even dangerous emesis is more frequently observed after chloroform than after ether. Thirdly, patients differ widely in their liability to these sequelæ. Rosy-cheeked children, young women of good colour and full lips, and flabby-looking individuals with an unhealthy and dusky appearance are much more likely to suffer from after-vomiting than others. Such patients nearly always secrete large quantities of mucus, which is swallowed and subsequently ejected. Similarly, patients with chronic naso-pharyngeal catarrh, whose stomachs contain swallowed mucus before the administration, are specially liable to after-vomiting. Patients of "bilious" habit frequently suffer a good deal after ether or chloroform—a fact recognised by Snow. Moreover, those who are liable to sea-sickness, as well as those whose digestion is upset by travelling on land, usually display nausea and vomiting after general anæsthesia. On the other hand,

elderly persons, alcoholic subjects, and muscular young men who have "lived hard" are rarely affected by these gastric sequelæ. Fourthly, the nature of the operation may possibly affect the question. Thus, it is believed by some surgeons that patients who have undergone operations in which the intestines have been freely manipulated, and particularly those upon whom oöphorectomy has been performed, are specially liable to after-vomiting. Dr. Sheppard states in his notes that he found vomiting to be rare after mouth and jaw operations; and Mr. Rigden makes the same observation. Lastly, the kind of anæsthetic employed must be considered. Although it is difficult to speak positively upon the point, the author believes that pure ethylic ether is less frequently followed by nausea and vomiting than the so-called "Pure Methylated" ether; and it is possible, although improbable, that certain kinds of chloroform may be superior to others in this respect. If, then, we wish to avoid after-vomiting, an appropriate laxative or purgative must be given; the diet carefully regulated; a deep anæsthesia with the purest anæsthetics maintained; the head kept turned well to one side for the escape of mucus and saliva; and the patient placed upon his side directly the operation is over.

If nausea and vomiting arise, and prove distressing to the patient, an endeavour must be made to relieve them. It is best, in the first instance, to give the patient a tumblerful of hot water to which has been added a small teaspoonful of bicarbonate of soda. The author has often known this treatment to completely arrest post-anæsthetic vomiting. Should it not do so, it may be repeated in a few hours' time. Small pieces of ice were formerly advocated, but hot alkaline water seems more efficacious. If vomiting persist, some strong hot coffee without milk or sugar may be next tried.[1] The author has notes of a case in which this treatment allayed vomiting which had lasted for twenty-four hours. He has also notes of a case in which obstinate after-sickness was immediately stopped by champagne; and a case has been reported to him by a surgeon in which obstinate nausea and retching after chloroform

[1] Dr. Buxton (*Anæsthetics*) speaks highly of the addition of bicarbonate of soda to coffee.

yielded to small doses of oxalate of cerium, after other remedies had failed. Kappeler recommends the application of an ice-bag to the epigastrium for after-sickness; but the author has had no experience of this remedy. The inhalation of vinegar is said to be of use in controlling vomiting after chloroform; but although this plan has been tried it does not appear to have many advocates. A small blister to the epigastrium will sometimes act beneficially in obstinate cases. . Lenevitch[1] advises washing out the stomach with luke-warm alkaline solutions in severe after-vomiting; and Blumfeld,[2] who employs plain water for the purpose, speaks favourably of this line of treatment.[3] When there appears to be a neurotic element in the vomiting, benefit may sometimes be derived from the use of an enema of bromide of potassium (about 30 grs. to a couple of ounces of water).

The author finds that the disagreeable taste left in the mouth after the inhalation of ether is best treated by giving the patient very thin slices of lemon with which to moisten his lips from time to time.

Respiratory complications are far more common after ether than after other anæsthetics, and the reader is therefore referred to Chap. X., in which these complications have been discussed in their relation to ether anæsthesia. They may, however, occur after other agents, and under these circumstances are generally attributable, at all events in large measure, to influences other than the anæsthetic itself. It is difficult to summarise these respiratory sequelæ, as they differ very considerably from one another, not only in their mode of origin but in their nature and degree. It would seem, however, that they are of four kinds:—

(1) Those which are primarily referable to the presence of some pre-existing bronchial or pulmonary affection, and secondarily, referable to the direct or indirect action of the anæsthetic.

(2) Those wholly referable to some inflammatory condition

[1] *Annual Univ. Med. Sci.*, 1892, p. 13.

[2] *Lancet*, 23rd September 1899, p. 833.

[3] In one case, that of a boy who had suffered on previous occasions from distressing vomiting after anæsthesia, the author washed out the stomach with hot alkaline water during the recovery period. The after-vomiting, however, was quite as severe as it had previously been.

of the lower respiratory passages coming on *de novo, i.e.* shortly after the administration of the anæsthetic.

(3) Those wholly referable to some congestive or œdematous condition of the lungs, also arising *de novo.*

(4) Those wholly referable to the entry of some solid or fluid substance into the air-passages during anæsthesia.

Respiratory complications of the first kind arise if ether be given for a short time or chloroform for a long time to a patient with chronic bronchitis, the chronic condition passing into an acute condition as the result of the local action of the anæsthetic. Similarly, a patient with quiescent pulmonary phthisis, who is subjected to a somewhat protracted operation upon the tonsils, may develop acute pulmonary symptoms as the result of blood or septic matter entering the bronchi. Or again, the presence of diaphragmatic paralysis may, as in Illustrative Case, No. 9, p. 363, predispose to acute pulmonary œdema after ether. Respiratory sequelæ of the second and third kinds seem to be almost exclusively met with after ether (see Chap. X., p. 359). As regards respiratory complications of the fourth class, these may obviously be met with after all anæsthetics. They are, however, more common after ether than after other agents, owing to the frequency with which ether causes an excessive mucous secretion within the bronchi. The various foreign substances, both solid and liquid, which may enter the respiratory passages during anæsthesia have been considered in Chap. XVIII. (p. 539); and it is clear that symptoms referable to the entry of these substances may, in certain cases, persist after the restoration of consciousness.

The preventive treatment of respiratory complications is an exceedingly important matter. There can be no doubt indeed, that by carefully selecting appropriate anæsthetics, and by judiciously administering them, these complications may, as a general rule, be completely prevented. In the first place, it is believed by a large number of surgeons that the exposure of anæsthetised patients to air-currents is a common cause of bronchial and pulmonary complications. There is, however, very little evidence to support this view. At the same time, it is certainly prudent to preserve an equable temperature

during anæsthesia, and to expose the patient as little as possible to draughts of cold air. In the next place, all respiratory embarrassment, whether from faulty posture, undue air-limitation, or other causes, should be avoided. Thirdly—and this is the most important point—the anæsthetic chosen should not be permitted to excite the secretion of mucus to any great extent. Ether is undoubtedly the agent which is most likely to produce respiratory after-effects. Speaking generally, we may say that this anæsthetic should not be given to patients liable to or suffering from respiratory affections; unless its vapour be well borne, it should not be used for any very prolonged period, particularly when the operation is within or about the abdomen; and its administration should not be unnecessarily pushed, as it often is at the present day. When ether is badly borne, *i.e.* when it produces much mucus and irritation, a change to some other anæsthetic should be effected *early in the administration.* If this rule be not followed, and if frothy mucus be allowed to accumulate for a considerable time within the air-passages, the state of the patient at the termination of the administration may be that described in the case referred to on p. 362. Mucus-inundation is certainly one of the special risks of ether anæsthesia, although it is a risk which is easily avoided by the encouragement of cough, or by the early substitution of chloroform. The moist rattling and laboured breathing which have of late years become such common accompaniments of surgical anæsthesia should in fact be taken as warning notes, indicating a tendency towards the occurrence of respiratory complications and the necessity for a lighter anæsthesia. Fourthly, the rule should be followed whenever practicable of keeping the patient's head turned well to one side for the escape of mucus; whilst in any case in which mucous secretion is excessive, the fauces should be frequently sponged out. Lastly, should the patient have displayed moist breathing during anæsthesia, whether from the presence of mucus, blood, or vomited fluid, it is important, at the conclusion of the administration, to keep him for some time in the lateral posture, substituting the right for the left side, and *vice versa*, at intervals, in order to encourage the free expansion of each lung.

For remarks on the renal complications of anæsthesia, the reader is referred to Chap. X., p. 366, and Chap. XI., p. 425.

Occasional reference has been made in preceding pages to a condition termed "**acid intoxication**" or **acidosis**—this being the name which would seem to be most appropriately applied to a peculiar state which, according to numerous recent observers, is not unfrequently met with, particularly in children, after the administration of a general anæsthetic. It is the same condition which has been occasionally described as "**delayed chloroform poisoning.**" Considerable caution is necessary in approaching this subject; for, in the present state of our knowledge, it is difficult to say, firstly, whether anæsthetisation is really responsible for the occurrence of this condition; and secondly, provided this responsibility can be established, what precise part the anæsthetic plays in bringing about the group of symptoms to be presently described. With one questionable exception the author has not, to the best of his knowledge, seen any case of this kind during the twenty or more years in which he has been in practice; but it is freely admitted that such cases might easily occur after administrations conducted by specialists without the latter ever being aware of their occurrence. The position of the matter at the present moment is that a large amount of clinical evidence has been brought forward to prove that anæsthetics, and particularly chloroform, may, under certain conditions, bring about a peculiar toxic state within the first few days after the administration. It is, therefore, our duty carefully to weigh this evidence and accept, for the moment, the proposition that these after-effects have a distinct connection with general anæsthesia.

As far back as 1850 Casper[1] expressed the belief that chloroform might leave behind it a state of "chronic poisoning," which might possibly terminate fatally hours, days, or even weeks after the administration. In the same year Langenbeck[2] reported a case in which a patient died from the supposed delayed action of chloroform seventeen hours after an

[1] Casper's *Wochenschrift*, 1850.
[2] Berend's *Chloroform Statistik*, 1850, Hanover.

operation. Within recent years numerous other cases have been recorded, particularly by Continental surgeons, in which the anæsthetic seemed to be the chief, if not the sole, cause of fatal symptoms arising after operations. Thus Heintz, Schenk, Fränkel, Bastanielli, Roth, Eisendraht, Ambrosius, Thiem and Fischer, Bandler and Cohn, have reported[1] such cases. The most noteworthy feature at the autopsies of many of these patients has been the presence of fatty changes either in the liver, heart, or kidneys, or in all of these organs. In some of the cases the liver changes were described as those of acute yellow atrophy, in others as of fatty degeneration or fatty infiltration. Reference has already been made (Chap. III., p. 92) to the fact that in the lower animals chloroform anæsthesia, and particularly protracted or repeated chloroform anæsthesia, may be followed by degenerative changes, chiefly of a fatty nature, in the liver, heart, kidneys, and muscles; and the question naturally presents itself: Is there any close connection between these cases of acid intoxication and the degenerative visceral changes observed in their post-mortem examinations? Leonard Guthrie[2] was the first observer in this country to direct attention to the cases now under consideration, and we are greatly indebted to him for much interesting clinical and pathological information. In 1894 he reported a number of cases which had come under his observation at a children's hospital, in which chloroformisation was followed by fatal after-effects of a toxic character. The symptoms were:—copious, violent, and persistent vomiting—the vomited matter often resembling beef-tea dregs; restlessness; loud screaming; delirium alternating with apathy; pyrexia towards the close of the case; and coma. In the fatal cases death usually supervened from exhaustion on or about the fifth day. Guthrie carefully discussed the possibility of these patients having died from "shock with excitement," sepsis, fat-embolism, poisoning by carbolic acid or other drugs used for dressings, uræmia and other conditions, and came to the conclusion that, at all events in several of his cases, the

[1] Guthrie, *Lancet*, 4th July 1903.

[2] *Lancet*, vol. i., 1894, p. 193, "Some Fatal After-effects of Chloroform in Children." See also *Lancet*, 4th July 1903, and *Lancet*, 26th Aug. 1905, p. 583.

anæsthetic was largely responsible. He laid stress on the fact that the liver was found to be markedly fatty in no less than five of his ten cases; and arguing that this fatty condition could hardly have resulted from the comparatively short chloroformisation which was recorded in some of those cases, he advanced the view that a fatty liver was probably present beforehand and acted as a predisposing factor. As the long-continued administration of chloroform eventually produces degenerative changes of a fatty nature in the liver, Guthrie urges that it is reasonable to suppose that this anæsthetic, even when administered for a short time to a patient with a fatty liver, may aggravate pre-existing fatty conditions, and, acting as the "last straw," produce symptoms which, under ordinary circumstances, would not occur. There is certainly considerable similarity between the symptoms described by Guthrie and those of acute yellow atrophy of the liver, although in all but one of Guthrie's cases [1] jaundice was absent. In a fatal case reported by Cohn, however, jaundice was a prominent feature.

The next step in the development of this subject was taken by Brackett, Stone, and Low,[2] of Boston, by the publication of a paper entitled "Aciduria (Acetonuria) associated with Death after Anæsthesia." These observers reported several cases in which symptoms somewhat similar to those observed by Guthrie came on after *ether* anæsthesia. The patients were children suffering, as a rule, from infantile paralysis. Observing a sweetish odour in the breath, the urine was examined and found to contain acetone and diacetic acid. They also reported several cases in which toxic symptoms of a similar character arose independently of any anæsthetic. The cases presented the following features in common: vomiting; collapse; weak and rapid pulse; an absence of fever until just before death; cyanosis in the fatal cases; apathy alternating with restlessness; coma; and the presence of acetone in the breath and urine. The symptoms in the seven operation cases reported did not come on until from twelve to twenty-four hours after the anæsthetic. They

[1] Cf. *Lancet*, vol. ii., 1903, p. 10.
[2] *Boston Medical Journal*, 7th July 1904, p. 3.

were, moreover, more severe than those in the non-operative cases, although one of the latter proved fatal. The marked post-mortem lesion in these cases was extreme fatty degeneration of the liver and muscles. These authors summarise the various conditions under which an increase in acetone excretion occurs. One of these is phosphorus poisoning, the acetone excretions taking place as the result of a destruction of fat tissue. They quote Schwarz's opinion that a similar explanation applies to acetone excretion after chloroform and other forms of narcosis. They believe that the toxic symptoms are due *to the fatty antecedents of acetone rather than to acetone itself*. The amount of acetone excreted did not afford any indication of the severity of the acid intoxication. Thus, in one of their fatal cases, the acetone excreted was small in amount. Brackett, Stone, and Low refer to observations made by Becker of Bonn, who found, as the result of about fifteen hundred anæsthetisations with different anæsthetics, that acetonuria was usually produced after anæsthesia. Reference has already been made (p. 177) to Becker's work in connection with diabetes. Becker found that acetonuria was specially liable to follow the anæsthetisation of children. Brackett, Stone, and Low, after a careful review of the whole subject, conclude that in their cases anæsthetisation alone "did not bring on the condition, or, at least, in a serious form."

In 1903 Guthrie[1] again contributed to the subject, describing in detail the case of a healthy-looking, well-nourished boy, aged three years, who was operated upon, under chloroform, for webbed fingers. The operation lasted about twenty minutes. Anæsthesia was uncomplicated. The next day but one vomiting came on, with drowsiness, apathy, and slight jaundice. Fits of screaming and semi-consciousness ensued. The liver was enlarged. Unconsciousness supervened, with constant vomiting, and the patient died somewhat suddenly eighty-four hours after the operation. The temperature throughout remained between 97° and normal. At the post-mortem examination the liver resembled those that Guthrie had seen in his other cases; it was of a pale fawn or buff

[1] "On the Fatal Effects of Chloroform on Children suffering from a Peculiar Condition of Fatty Liver," *Lancet*, July 1903.

colour, the fatty change affecting the whole organ. It was similar in many respects to the liver found in acute yellow atrophy.

In the following year Stiles and M'Donald[1] reported several cases of "delayed chloroform poisoning," giving an exhaustive and chronological epitome of the literature of the subject up to the date of their paper.

In 1905 three noteworthy papers appeared. The first of these was by Kelly[2] of Boston, who recorded forty-six cases of acid intoxication amongst four hundred hospital patients. Kelly gives a long list of conditions, both medical and surgical, in which an excess of acetone and diacetic acid may be met with in the urine, apart altogether from general anæsthesia, although general anæsthesia may itself constitute a cause. According to him the presence of acetone (·02 gramme in 50 oz.) as a normal constituent of urine has been proved by physiologists. The second noteworthy contribution during 1905 was by Scott Carmichael and Beattie,[3] who reported a case of so-called "delayed chloroform poisoning." Coffee-ground vomiting and extreme pallor were the prominent symptoms; delirium, screaming, and jaundice were absent. At the post-mortem the liver was found distinctly enlarged, intensely fatty, and almost canary yellow in colour. Microscopically, the liver cells were markedly vacuolated. "In freshly prepared sections stained for fat it was seen that all the cells from the centre to the periphery of the lobules were crowded with fat globules." The kidneys and supra-renal bodies also showed fatty degeneration. The authors state that, like Stiles and M'Donald, they cannot agree with Guthrie that the fatty liver of chloroform poisoning can be distinguished from the fatty liver of sepsis. They are by no means certain, indeed, that the pathological conditions found in their case were not wholly of septic origin; although they believe the fatty changes to have been due to chloroform. They refer to the fact that one of them has shown that extreme fatty degeneration in the liver and kidneys can be produced in healthy rabbits in from twenty-four to twenty-six hours after injection

[1] *Scottish Med. and Surgical Journal*, Aug. 1904, p. 97.

[2] "Acid Intoxication: its Significance in Surgical Conditions" (*Annals of Surgery*, Feb. 1905, p. 161).

[3] *Lancet*, 12th Aug. 1905, p. 437.

of the bacillus diphtheriæ. The third noteworthy paper during 1905 was contributed by Bevan and Favill[1] of Chicago. These authors report, with the greatest attention to detail, the case of a female patient of 12½ years, who died with toxic symptoms similar to those described by Guthrie and others after chloroformisation for an abdominal section, necessitated by the presence of a gangrenous ovarian cyst. The operation "was a rather short one." The patient did well for 48 hours. She then became slightly incoherent and frightened. Delirium, screaming, muscular rigidity, exaggerated tendon reflexes, ankle clonus, rising pulse and temperature, moderate cyanosis, and coma supervened, and she died 110 hours after operation. Towards the close of the case distinct signs of cardiac dilatation appeared, loud bruits becoming audible. The urine was negative before the operation, but on the third day after the operation it was "highly concentrated," "with an acidity of 11·6, containing diacetic acid, a trace of acetone, and one and one-fourth (1·25) grams per litre of albumin, and a number of hyaline, granular, and waxy casts." The next day albumin and diacetic acid were still present, and a little blood. The breath had a sweetish acetone odour. At the autopsy the liver was found enlarged and yellow in colour; microscopically there were advanced fatty changes at the periphery of the lobules. There were also chronic fibrous changes in the kidneys, with a "large amount of granular material (coagulated serum) in the cavities of the glomeruli visibly compressing many of the tufts." A similar granular material was observed in the convoluted tubules. The authors carefully discuss the case, and come to the conclusion that the symptoms pointed to acid intoxication rather than to sepsis.

The most recent contribution to this subject is one by Beesly.[2] According to this author, the clinical similarity of the symptoms described as occurring in so-called acid intoxication, acidosis, acetonuria, and delayed chloroform poisoning seems to point to a similar metabolic disturbance in the

1 "Acid Intoxication and late Poisonous Effects of Anæsthetics" (*Journ. Amer. Med. Assoc.*, 2nd Sept. 1905, p. 691).

2 "Post-Anæsthetic Acetonuria: the Significance of Delayed Chloroform Poisoning, and the Advantages of Ether over Chloroform in Acute Infective Conditions" (*Brit. Med. Journ.*, 19th May 1906, p. 1142).

organism, one of the ultimate products of which is acetone. This product, which is met with under numerous other circumstances, occurs with the greatest regularity after general anæsthesia. We have already referred to Becker's results in this direction. Beesly maintains that a certain degree of acid intoxication takes place after every surgical operation in which a general anæsthetic is given. He carefully examined the urine of a large number of children at the Royal Hospital for Sick Children, Edinburgh, before and after anæsthesia. The patients ranged from 4 to 12 years of age. Beesly found both ether and chloroform invariably produced a temporary acute acetonuria; but if acute acetonuria were previously present, chloroform proved to be far more dangerous than ether. Thus, of 19 cases of acute appendicitis operated upon under chloroform no less than 14 died, all exhibiting symptoms of acid intoxication or acetone poisoning. In 11 autopsies, fatty degeneration of liver, kidneys, and heart was present. Of 24 patients operated upon under ether only 2 died, and not as the result of acid intoxication. Beesly's most important deductions are that symptoms of intoxication only occur when the kidneys are failing to excrete the acetone, and that when death takes place it is due to the inability of these organs to meet abnormal demands made upon them. According to this author, the symptoms of acetonuria may be mitigated by the administration of alkalis, which may also be given with advantage before operations if poisoning be anticipated. It is recommended that sodium bicarbonate be pushed in such doses that the urine becomes alkaline. In two cases in which sodium bicarbonate was given (gr. xv. ter die) for eight days before operation, the results were very satisfactory, there being a better recovery from anæsthesia and no vomiting. It is also important to secure free skin action. Subcutaneous saline infusions and general stimulants are recommended in cases attended by collapse.

It will be seen from the foregoing remarks that there is considerable evidence that, under certain conditions, the nature of which is not yet accurately known, anæsthetics may bring about certain degenerative fatty changes within the liver, as the result of which the circulation of the patient becomes

charged with poisonous fatty acids, the precursors of acetone, so that a toxic state is established. Whether some similar change within the kidneys is an essential accompaniment of the liver changes, thus preventing renal elimination, it is at present impossible to say. The whole subject is indeed in an uncertain state, and it would be unwise, as it now stands, to attempt any further conclusions concerning it.

Certain other **exceptional sequelæ** may be met with after general anæsthesia. These have been referred to in Chapters IX., X., and XI. (pp. 290, 367, and 425) when discussing the special after-effects of nitrous oxide, ether, and chloroform respectively.

Finally, certain **posture-paralyses** may be met with in patients who have been anæsthetised. These have already been discussed (p. 247).

GENERAL INDEX

INDEX OF AUTHORS QUOTED

THE END

Printed by R. & R. Clark, Limited, *Edinburgh.*